Hunting for squarks and gluinos in less conventional scenarios with ATLAS

SUSY 2018, Barcelona

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ATLAS EXPERIMENT

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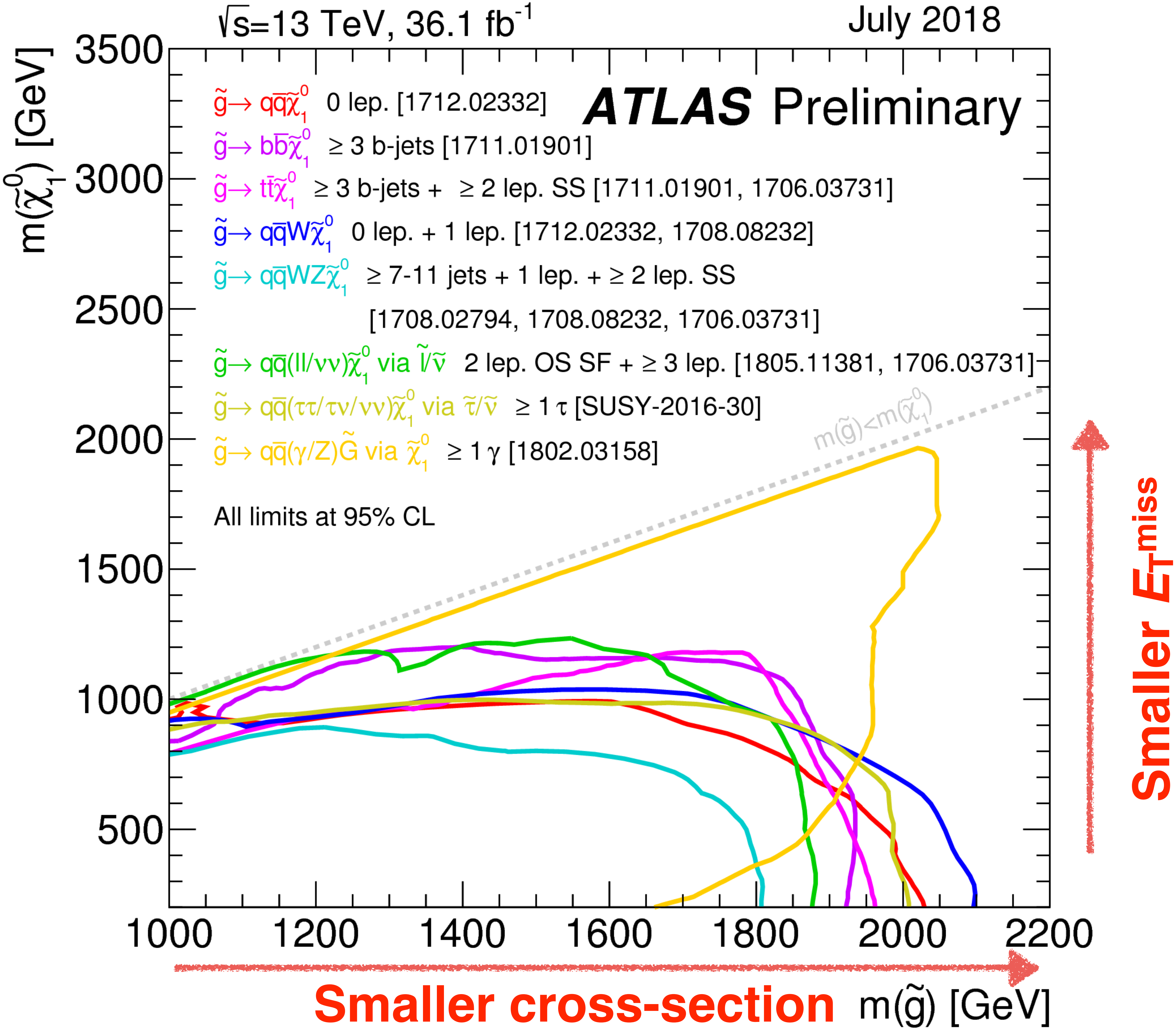
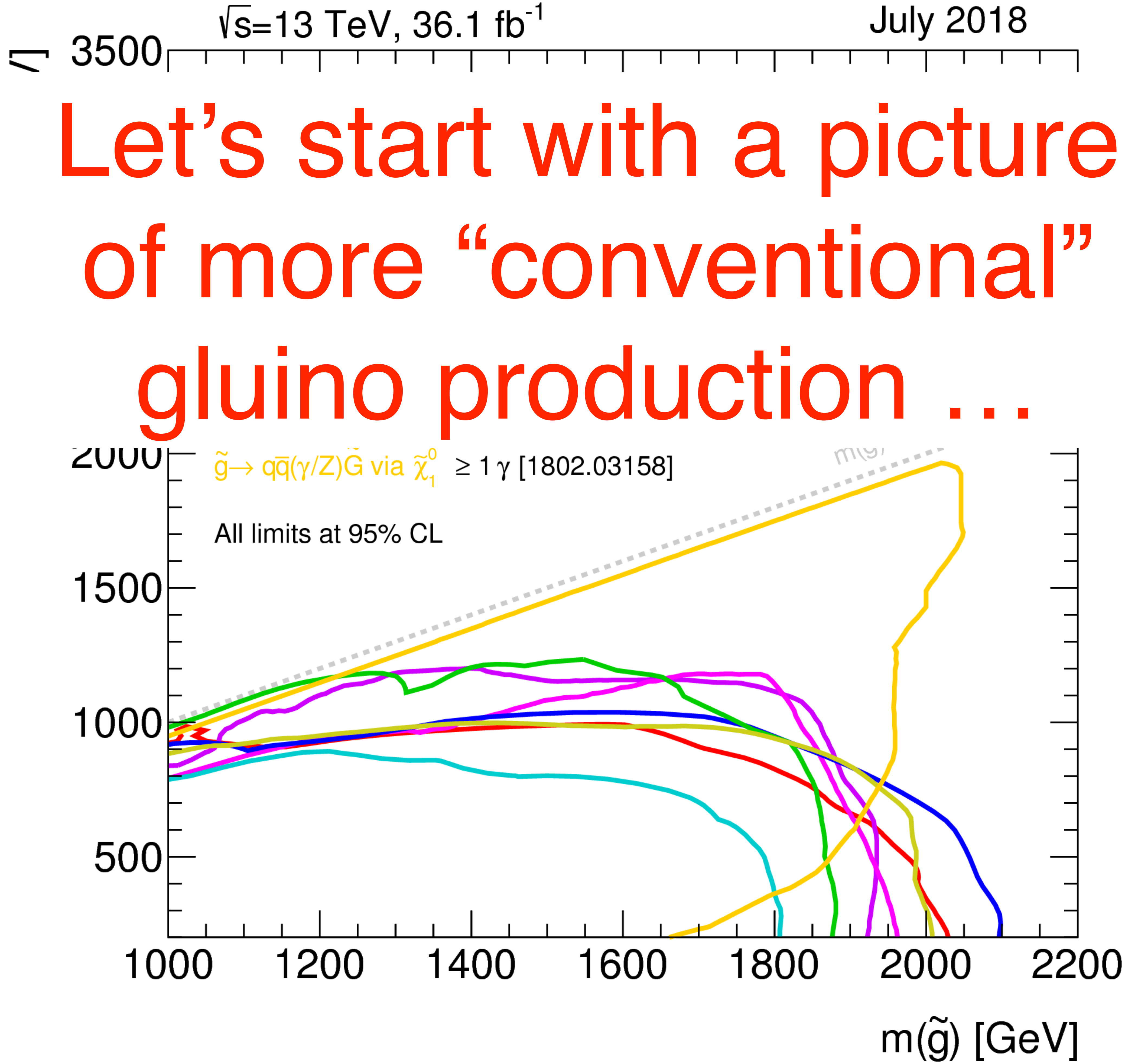


√s=13 TeV, 36.1 fb^-1
July 2018
ATLAS Preliminary
g̃→ qq̄χ̃⁰₁ 0 lep. [1712.02332]
g̃→ bb̄χ̃⁰₁ ≥ 3 b-jets [1711.01901]
g̃→ tt̄χ̃⁰₁ ≥ 3 b-jets + ≥ 2 lep. SS [1711.01901, 1706.03731]
g̃→ qq̄Wχ̃⁰₁ 0 lep. + 1 lep. [1712.02332, 1708.08232]
g̃→ qq̄WZχ̃⁰₁ ≥ 7-11 jets + 1 lep. + ≥ 2 lep. SS [1708.02794, 1708.08232, 1706.03731]
g̃→ qq̄(ll/νν)χ̃⁰₁ via l̃/ν̃ 2 lep. OS SF + ≥ 3 lep. [1805.11381, 1706.03731]
g̃→ qq̄(ττ/τν/νν)χ̃⁰₁ via τ̃/ν̃ ≥ 1 τ [SUSY-2016-30]
g̃→ qq̄(γ/Z)G̃ via χ̃⁰₁ ≥ 1 γ [1802.03158]
All limits at 95% CL
m(g̃)<m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(g̃) [GeV]
Smaller cross-section
Smaller E_T^miss

Let’s start with a picture of more “conventional” gluino production …



First, A Picture of “Conventional” Supersymmetry (SUSY)

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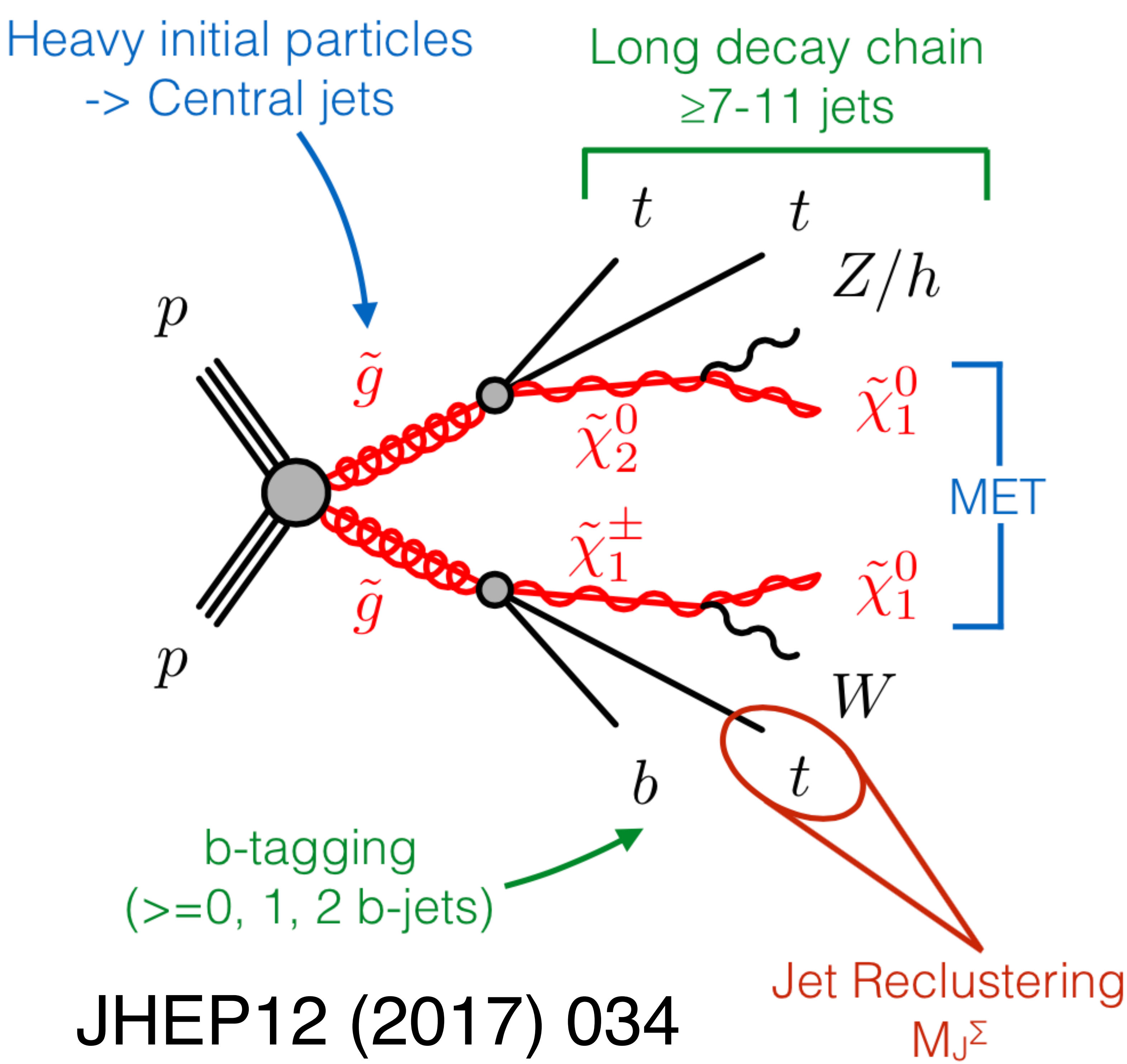


JHEP12 (2017) 034

Common Selection

Lepton veto

Many central jets: |η|<2.0

Key variable: MET-significance:

$$E_{\mathrm{T}}^{\mathrm{miss}} / \sqrt{H_{\mathrm{T}}}$$

$$H_{\mathrm{T}} = \sum p_{\mathrm{T,jet}}$$

Two analysis streams

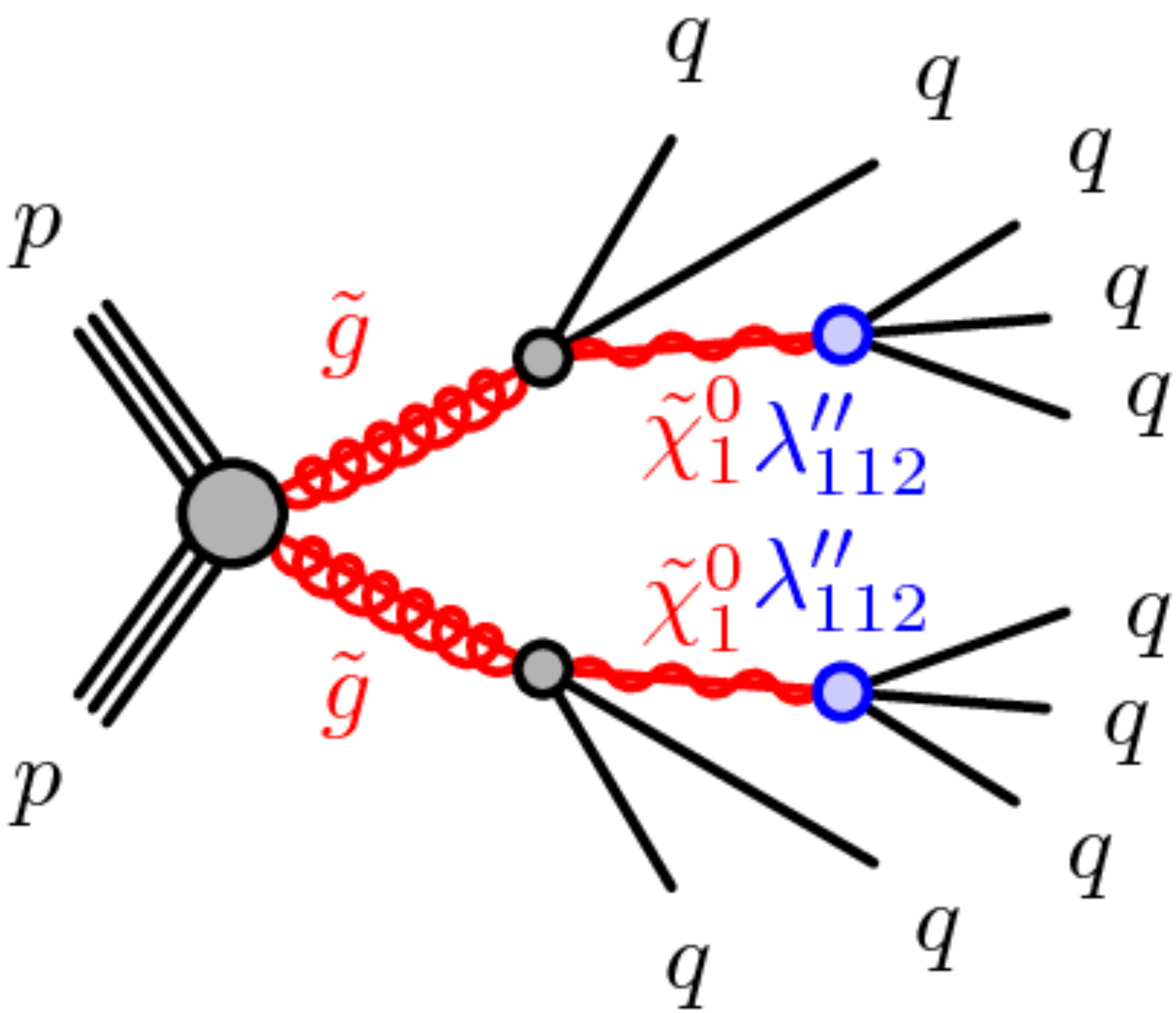
Flavour: select b-jets

MJSigma: makes use of jet reclustering

$$M_J^{\Sigma} = \sum_j m_j^{R=1.0}$$

Can we use existing jet multiplicity and E_T^{miss} techniques to extend sensitivity to **different gluino/squark production scenarios ?**

A Picture of *R*-parity-violating SUSY



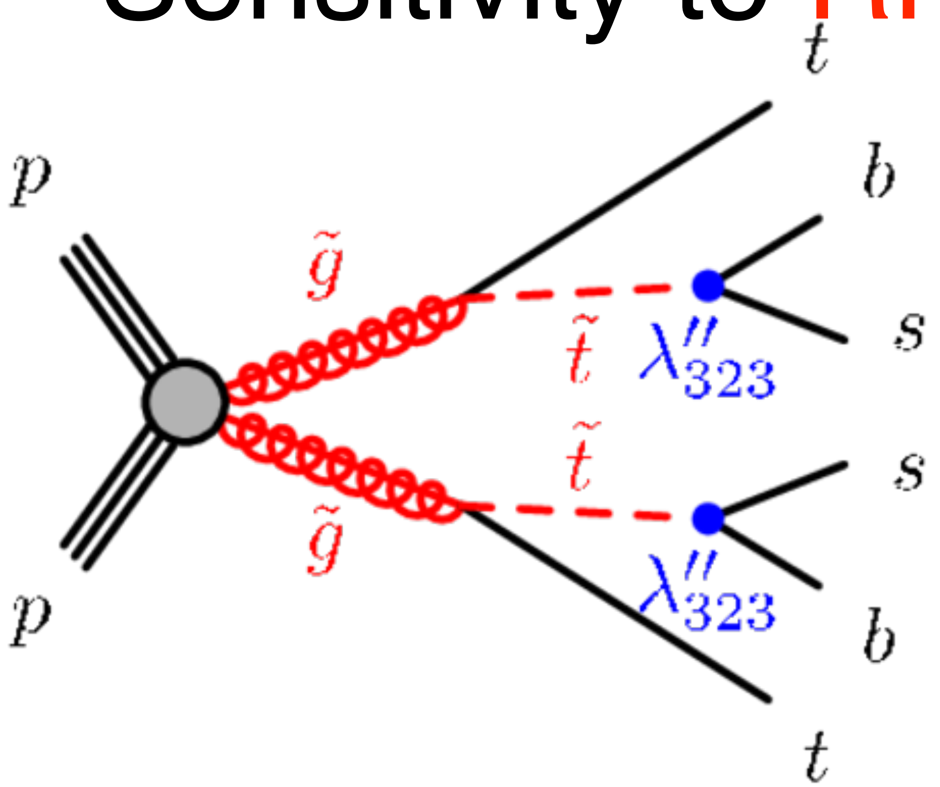
- Introduce a **baryon number-violating coupling, λ''_{ijk}** (i,j,k = quark generation indices).
- **RPV => LSP decays to SM particles**, with a decay probability characterised by λ''_{ijk}
- Another decay cascade => many hadronic jets in the final state.
- Range of LSP lifetimes possible, e.g. long-lived LSP => search for displaced tracks in the inner detector.

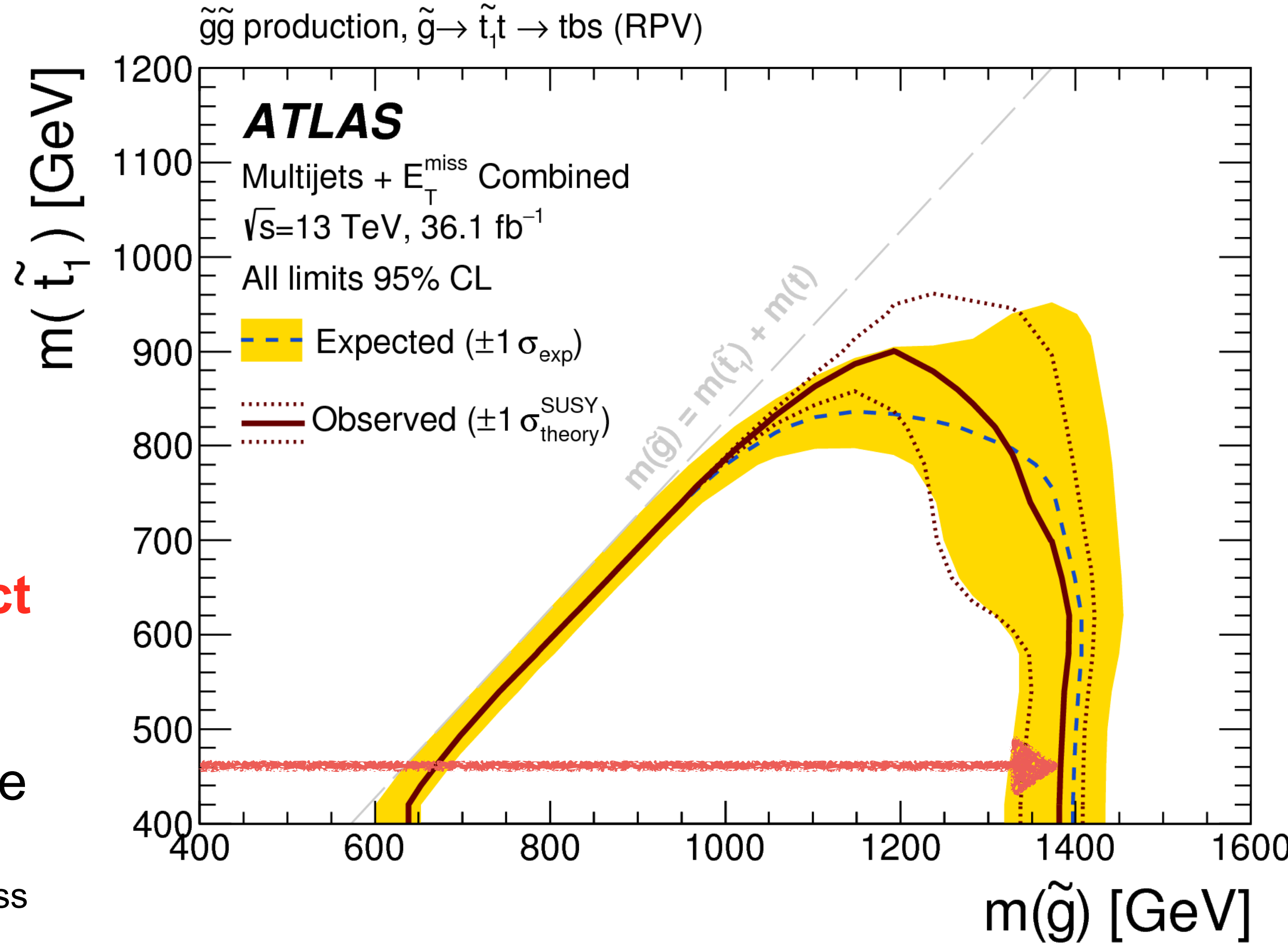
$$W_{RPV} = \lambda_{ijk} L_i L_j e_K^c + \lambda'_{ijk} Q_i L_j d_k^c + \lambda''_{ijk} u_i^c d_j^c d_k^c + m_i L_i H_u$$

Lepton number-violating

Baryon number-violating

Example: 7 — 11 Jets (RPC) Sensitivity to RPV SUSY (2015 + 2016)





- RPV stop: **stop undergoes a direct decay into heavy-flavour quarks**.
- The 7 — 11 jets analysis is sensitive to such a model because its SRs contain a small amount of real E_T^{miss}
- More in **JHEP12 (2017) 034**

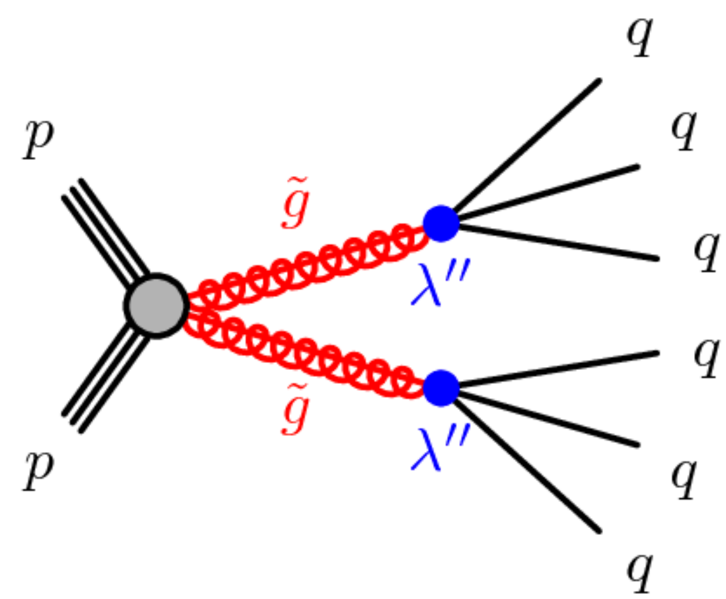
- More sensitive than most other strong-SUSY-motivated analyses, which have an explicit E_T^{miss} cut.

The RPV Programme at ATLAS

Analysis	Data	Paper
RPV 1L (multi-jets)	13 TeV, 36.1 fb^{-1}	1704.08493
RPV 0L (multi-jets)	13 TeV, 36.1 fb^{-1}	1804.03568
2 same-sign/3 leptons	13 TeV, 36.1 fb^{-1}	1706.03731
2 *x* 2 jet resonance search	13 TeV, 36.1 fb^{-1}	1710.07171
RPV 4L	13 TeV, 36.1 fb^{-1}	1804.03602
Stop B — L	13 TeV, 36.1 fb^{-1}	1710.05544

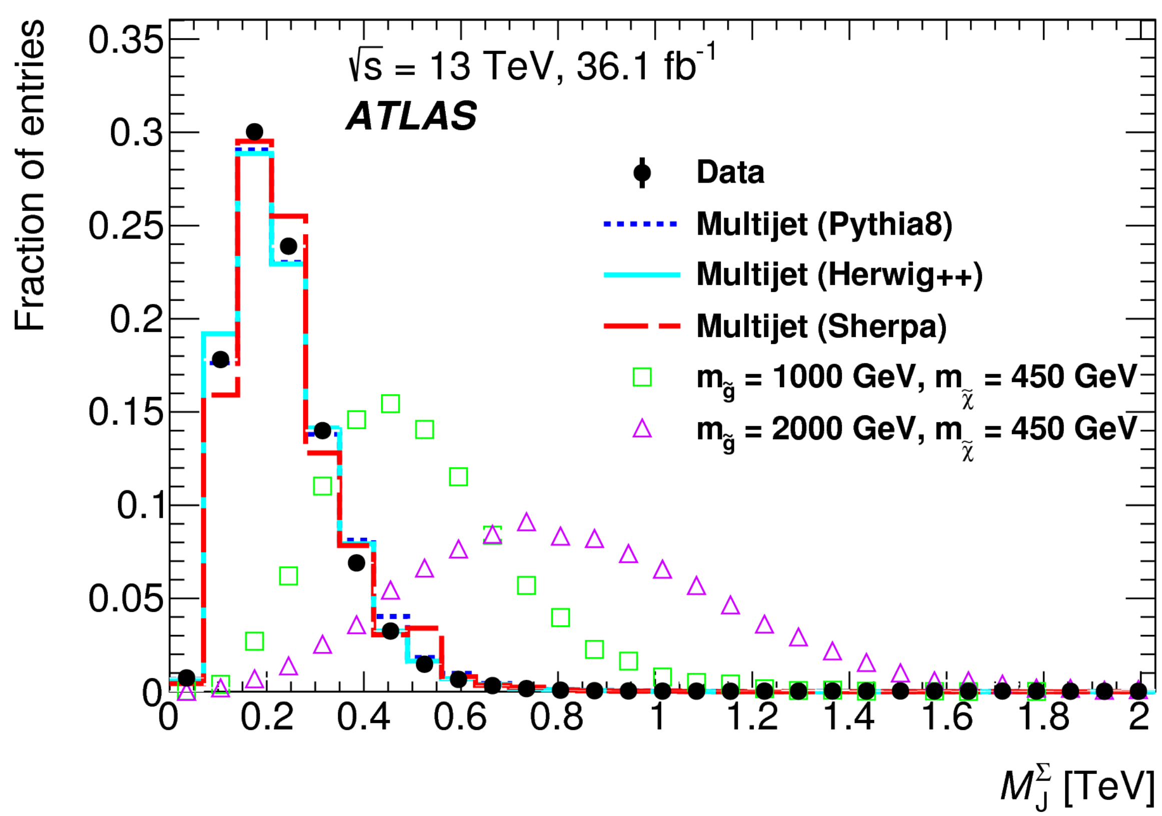
RPV Search with Multi-Jets

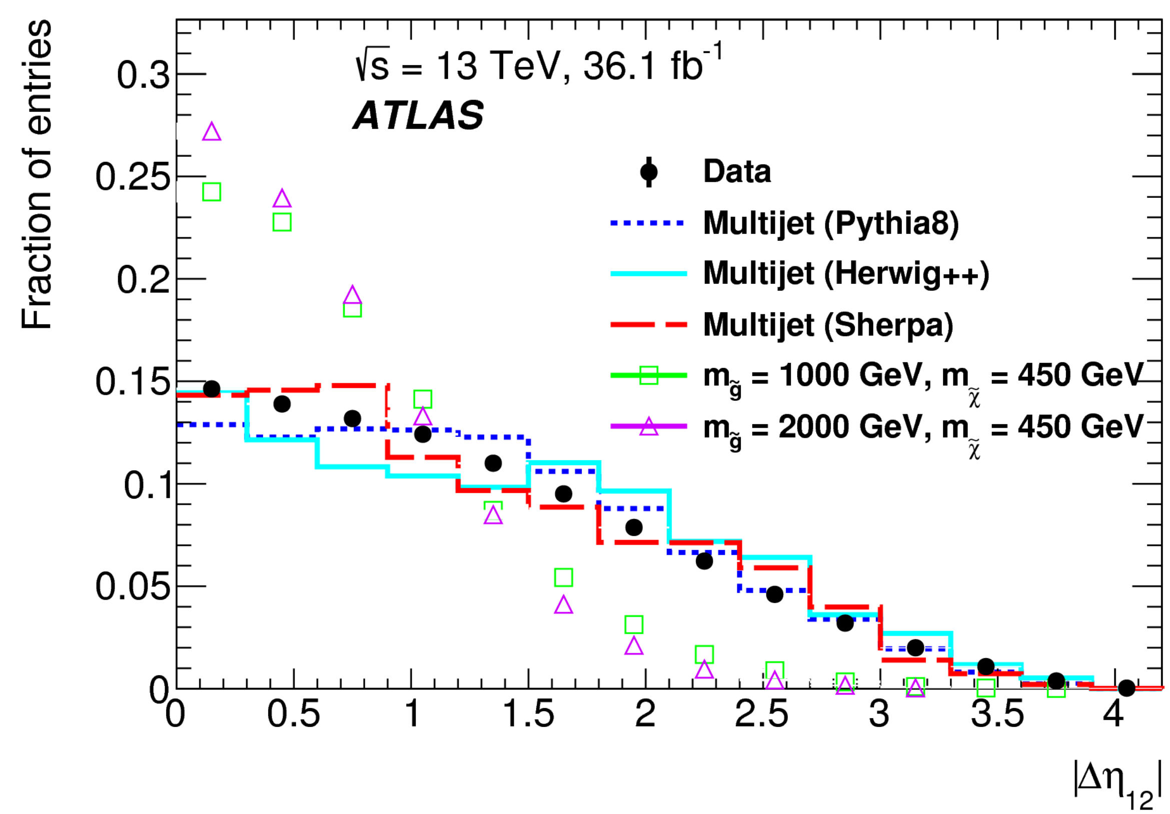
- RPV models with **gluino direct/cascade decays** into jets. Search in 2015 + 2016 ATLAS data.



- Construct signal regions from trimmed, ***R* = 1.0 jets** (4+, 5+), associated ***b*-jets**, and centrally-produced jets, **$|\Delta\eta_{12}| < 1.4$**.

- Uses **M_J^Σ of 4 leading *R* = 1.0 jets**, and estimates backdrop shape with data-driven template approach.





RPV Search with Multi-Jets

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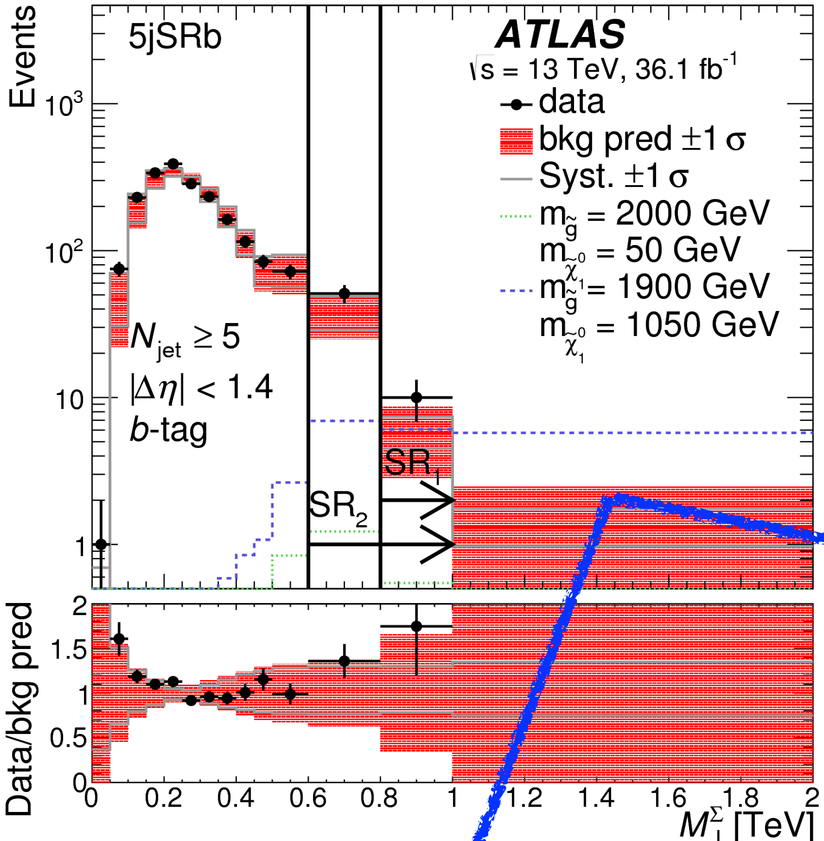
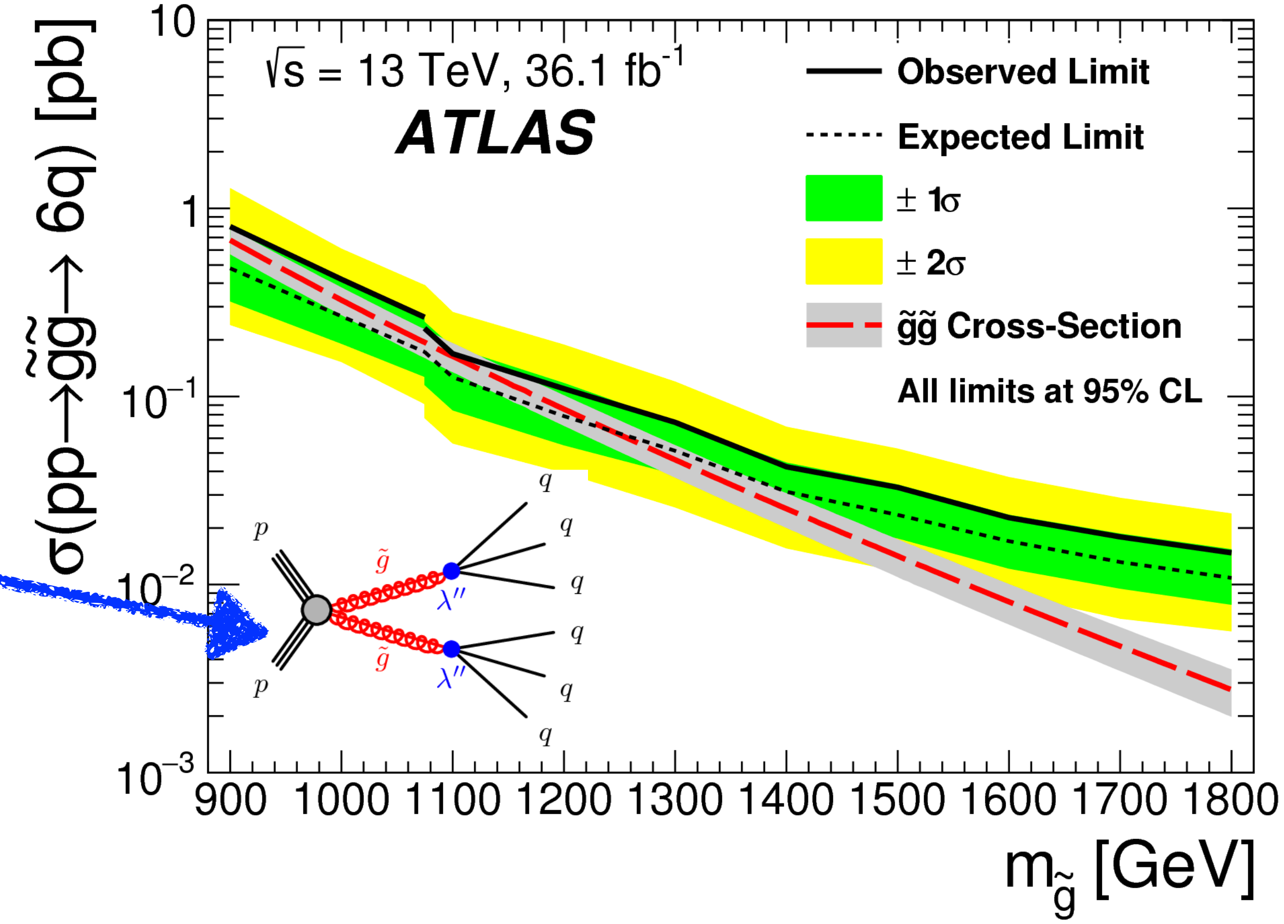
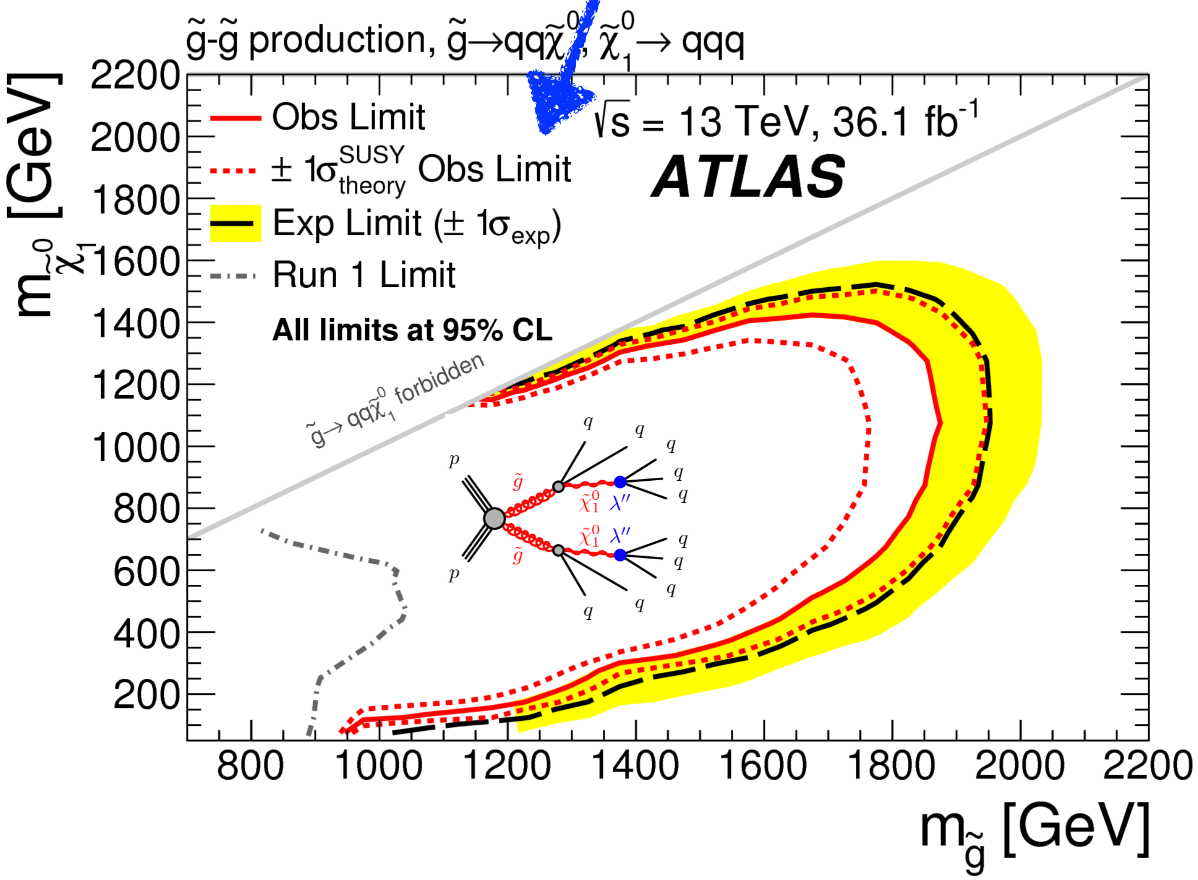
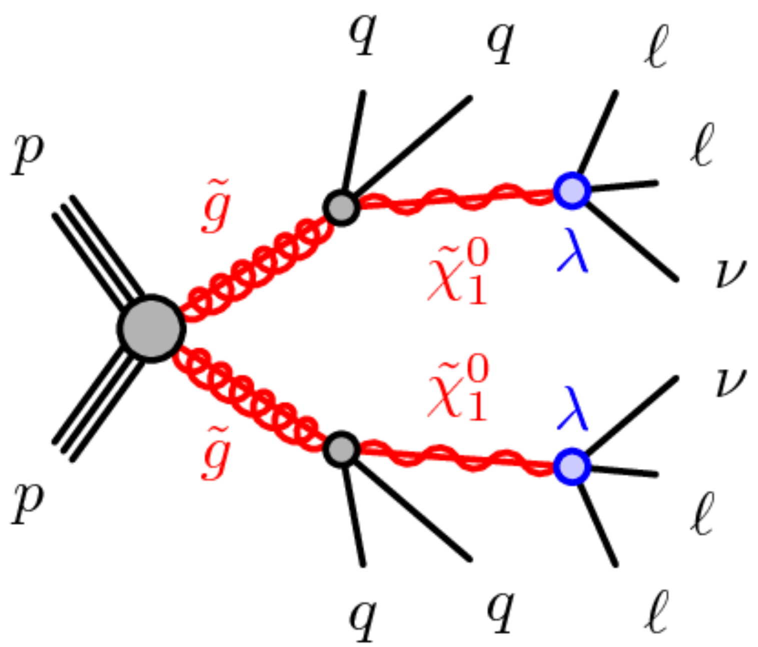


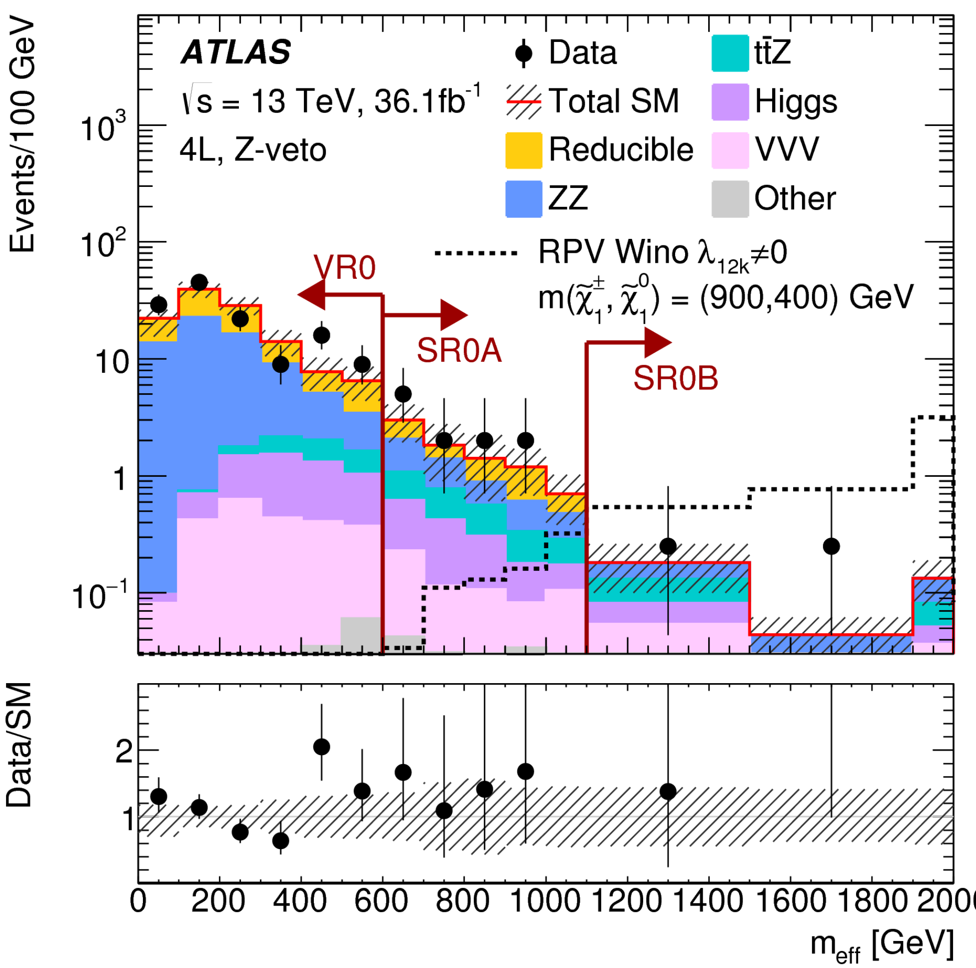




- **No statistically significant excesses** in 4+ or 5+ R = 1.0 jet signal regions, with/without b-tagging requirements.
- Direct decay: signals as small as **0.011 — 0.8 pb** excluded at 95 % CL.
- Cascade decay: excluding gluinos up to **masses of 1875 GeV** at 95 % CL.

RPV Search with Multi-Leptons





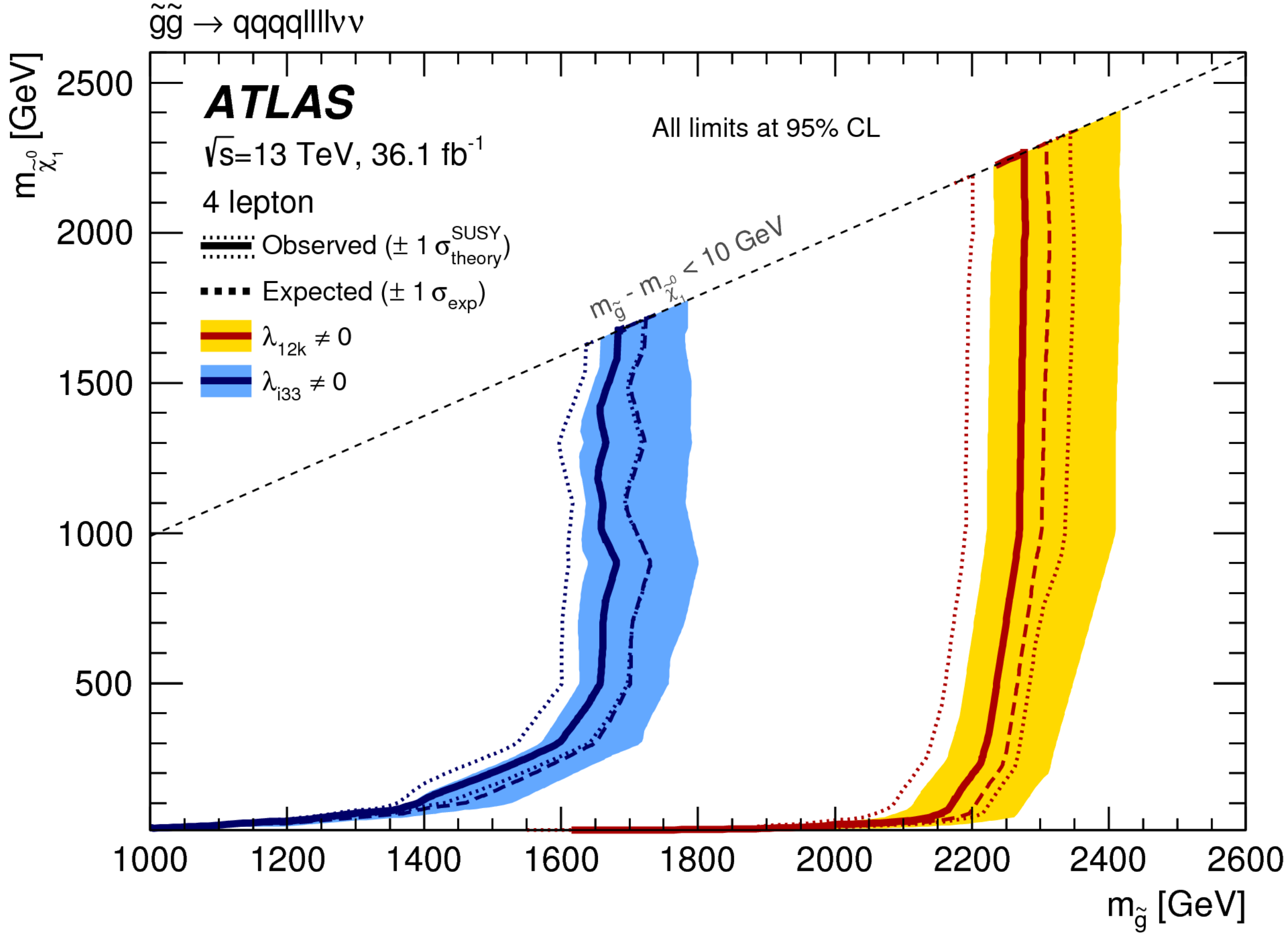
- Search for RPV **lepton-number-violating** decays. See also Matt Klein's talk and Zinonas Zinonos' poster !
- Inclusive search for decays to all **three leptonic generations** (*12k* and *i33*).

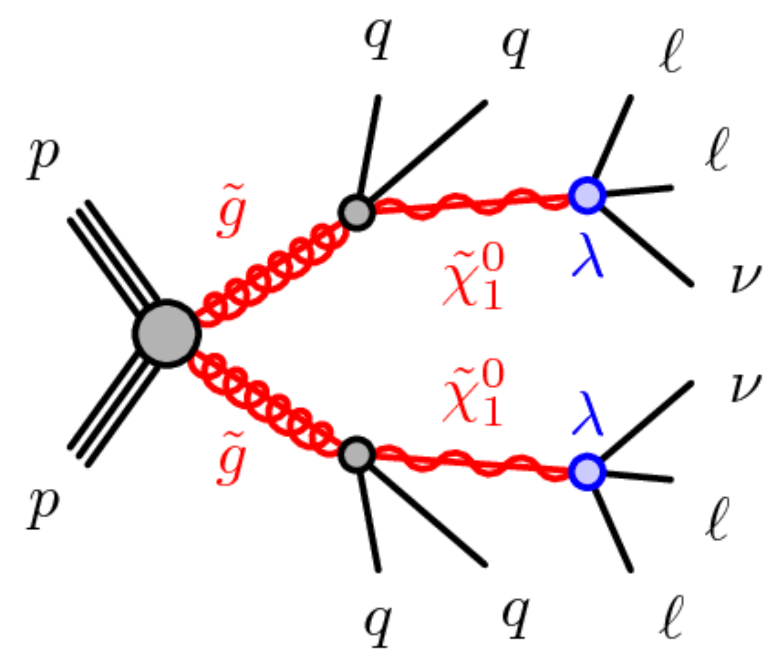
Scenario	$\tilde{\chi}_1^0$ branching ratios		
$LL\bar{E}12k$	$e^+e^-\nu$ (1/4)	$e^\pm\mu^\mp\nu$ (1/2)	$\mu^+\mu^-\nu$ (1/4)
$LL\bar{E}i33$	$e^\pm\tau^\mp\nu$ (1/4)	$\tau^+\tau^-\nu$ (1/2)	$\mu^\pm\tau^\mp\nu$ (1/4)

- Inclusive 4L0T, 3L1T, 2L2T signal regions (L = light lepton, T = tau).
- Same-flavour-opposite-sign lepton pairs with **dilepton mass around the *Z* peak are vetoed**.
- Multiple high-energy leptons => larger effective mass in signal,

  $m_{eff} = E_T^{miss} + \sum p_T^{leptons} + \sum p_T^{(>40\ GeV),jets}$

RPV Search with Multi-Leptons





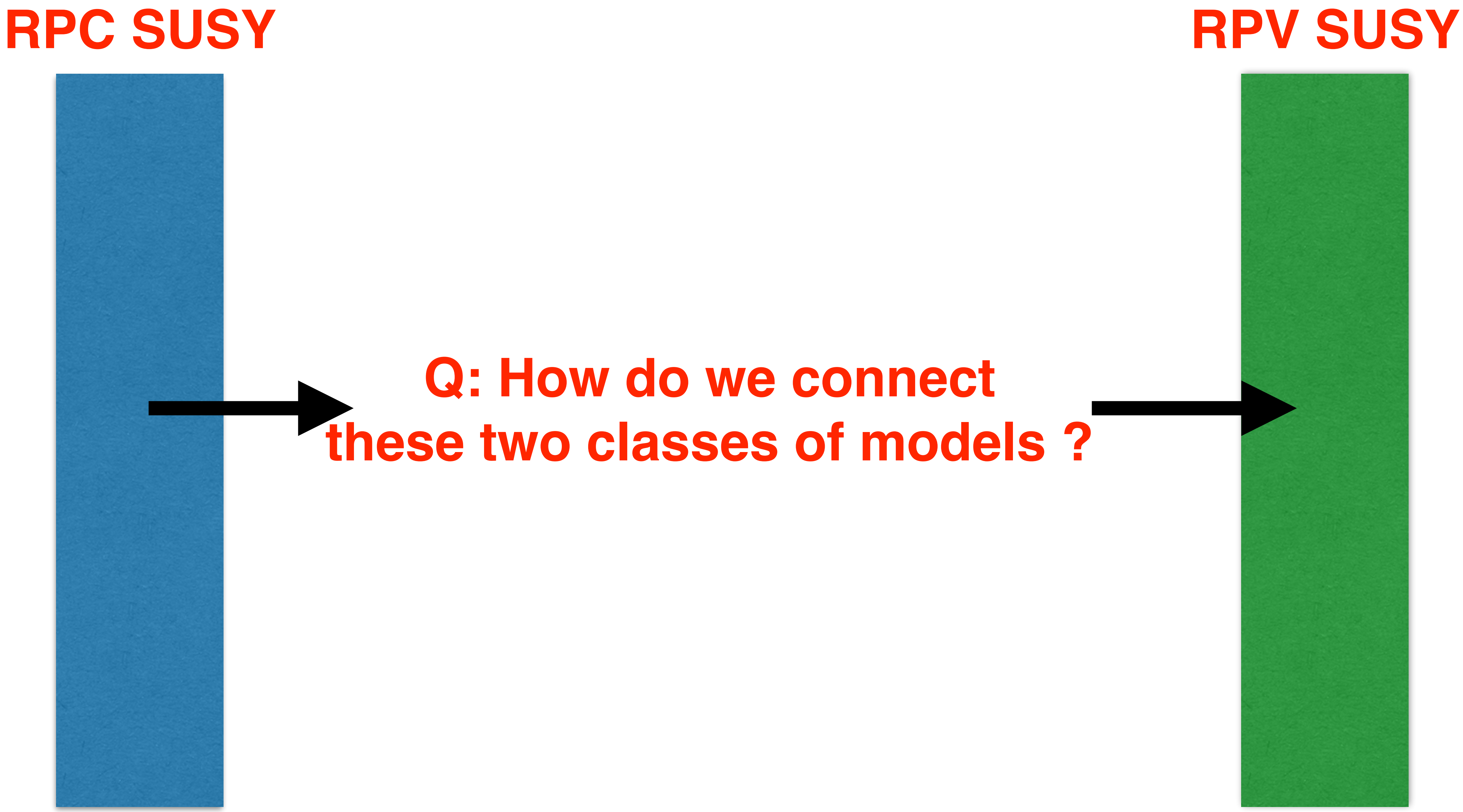
- First **2015 + 2016 limits** on both the *12k* and *i33* lepton-number-violating decays in gluino production.

- Gluino masses (*i33* coupling) **excluded up to 2.25 TeV** with 36 fb^{-1} of ATLAS data.

Can we **connect** these RPC—RPV Models ?

How do we connect the RPC and RPV pictures ?

- Most ATLAS SUSY analyses “optimised” to search for RPV or RPC SUSY.
- Can we explore sensitivity to both sets of models ?



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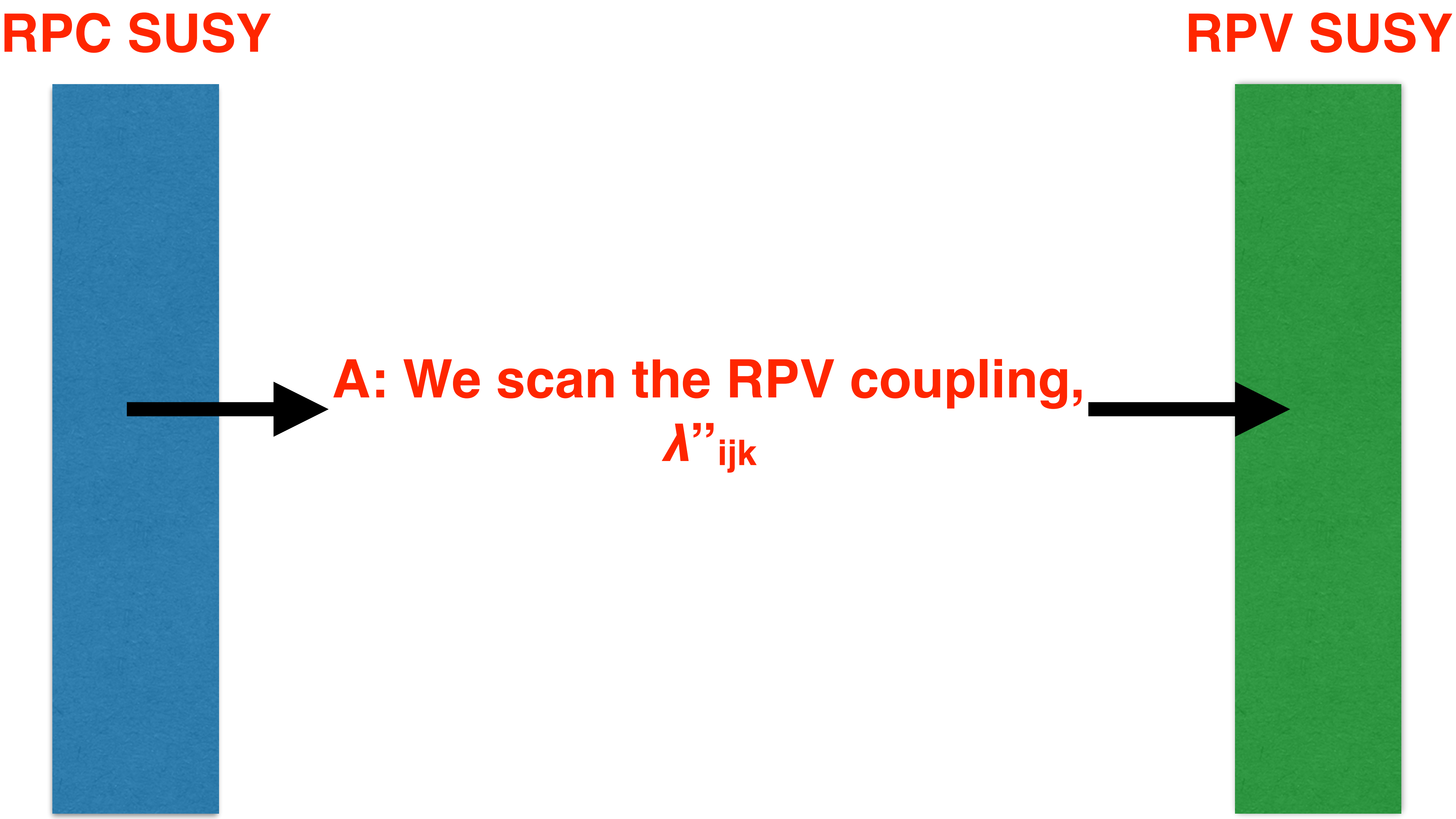

The RPC-meets-RPV “Continuum”

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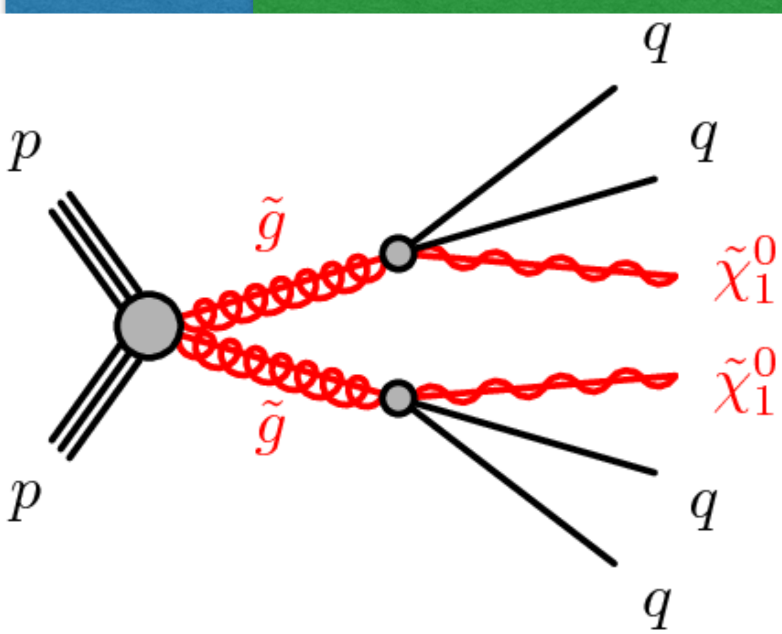
RPC-SUSY **RPV-SUSY**

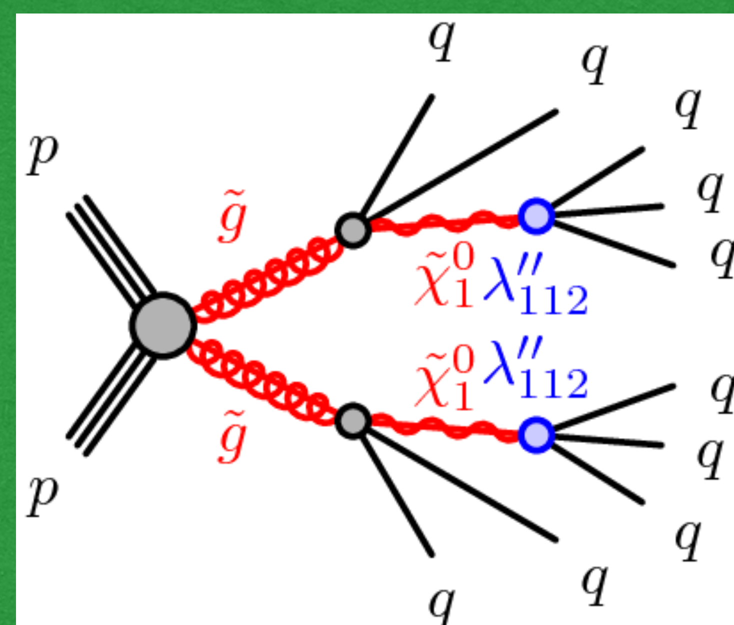
Increase RPV coupling strength, λ''_{ijk}

0 →

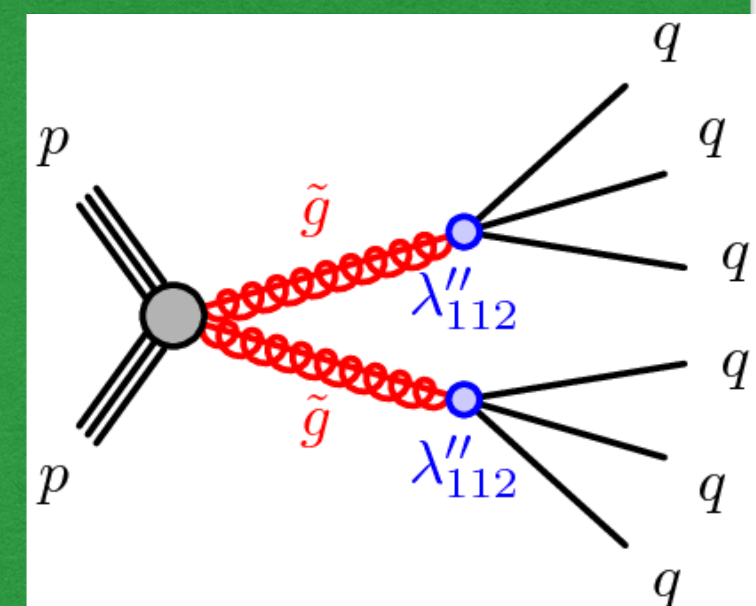
Stable LSP



Decaying LSP



Direct RPV Decay

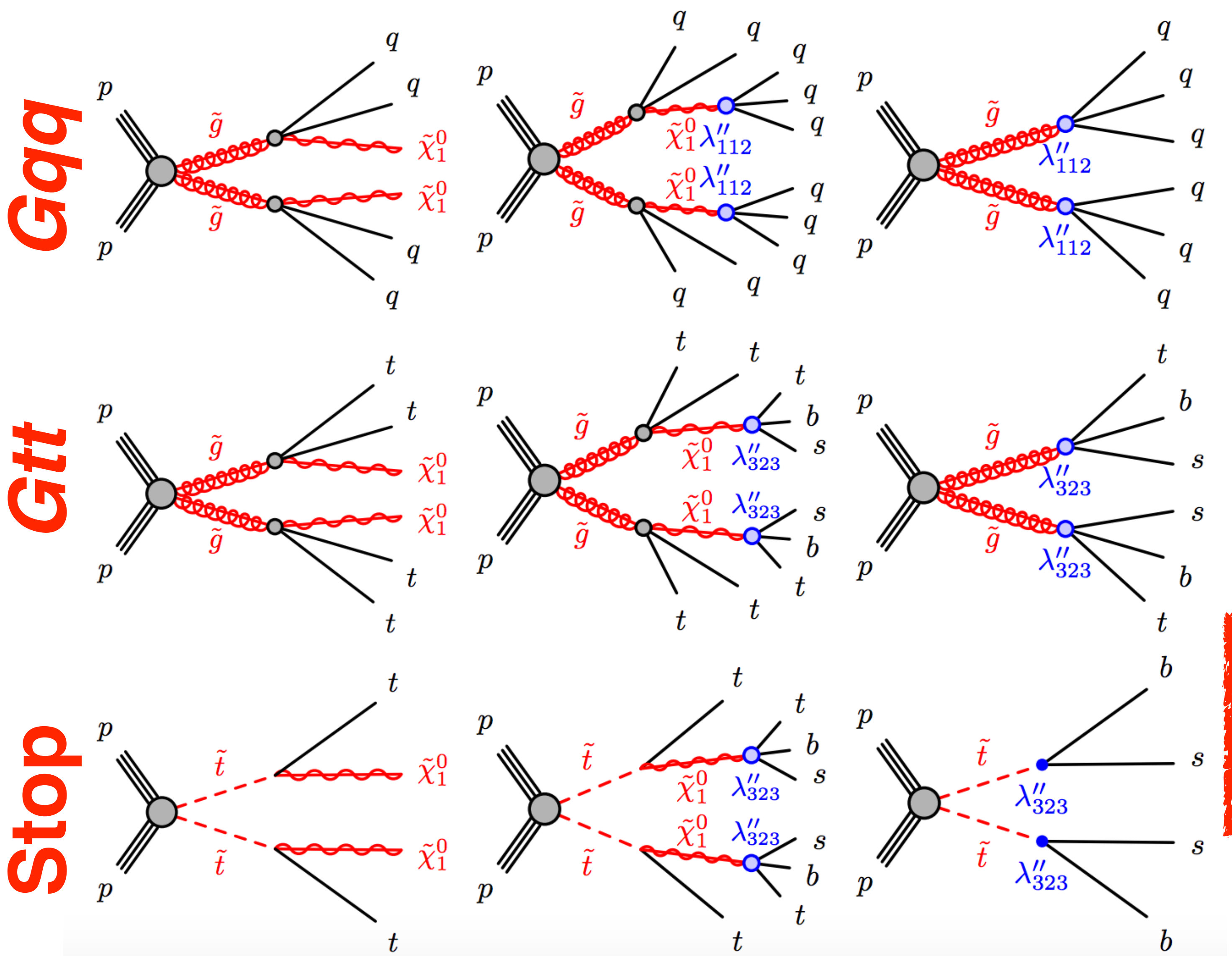


Distance LSP travels from beam line in ATLAS, *L*

← **0**

RPC-meets-RPV in ATLAS

- Idea: **reinterpret existing 36 fb^{-1} SUSY analyses** in the RPC-RPV "continuum" λ''_{ijk}
- Three types of "simplified" SUSY models considered: *Gqq*, *Gtt*, stop
- Full glory here: **ATLAS-CONF-2018-003**. See also Veronika Magerl's and Simone Amoroso's posters !



λ''_{ijk} →

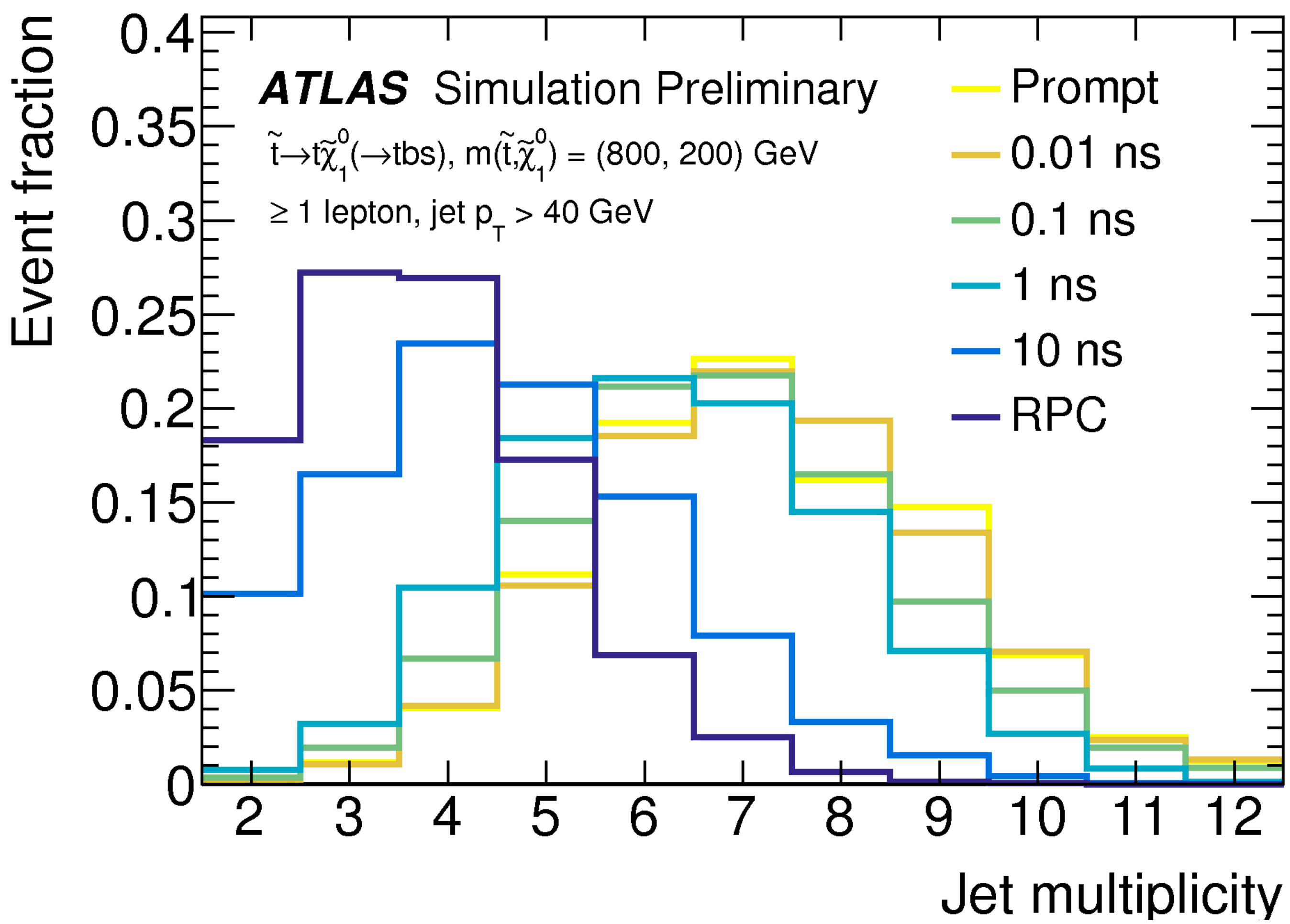
← L

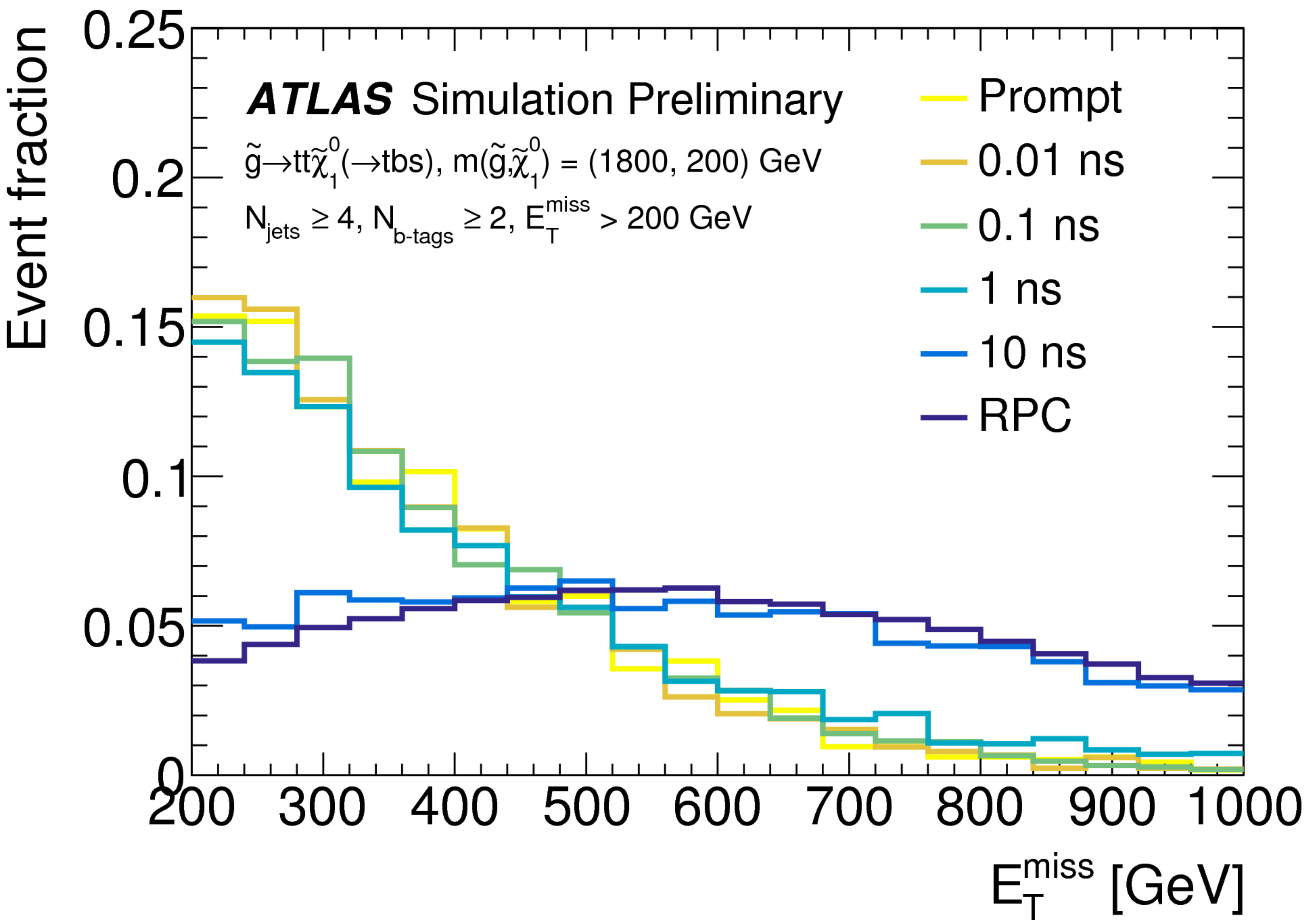
$$L(cm) = \frac{0.9\beta\gamma}{\lambda''^2}\left(\frac{m(\tilde{q})}{100\ \text{GeV}}\right)^4\left(\frac{1\ \text{GeV}}{m(\tilde{\chi}_1^0)}\right)^5$$

For bino-like neutralinos

RPC-meets-RPV Kinematics

- Let's understand the kinematics of the various RPC-RPV signals to see if existing squark/gluino searches could be sensitive …

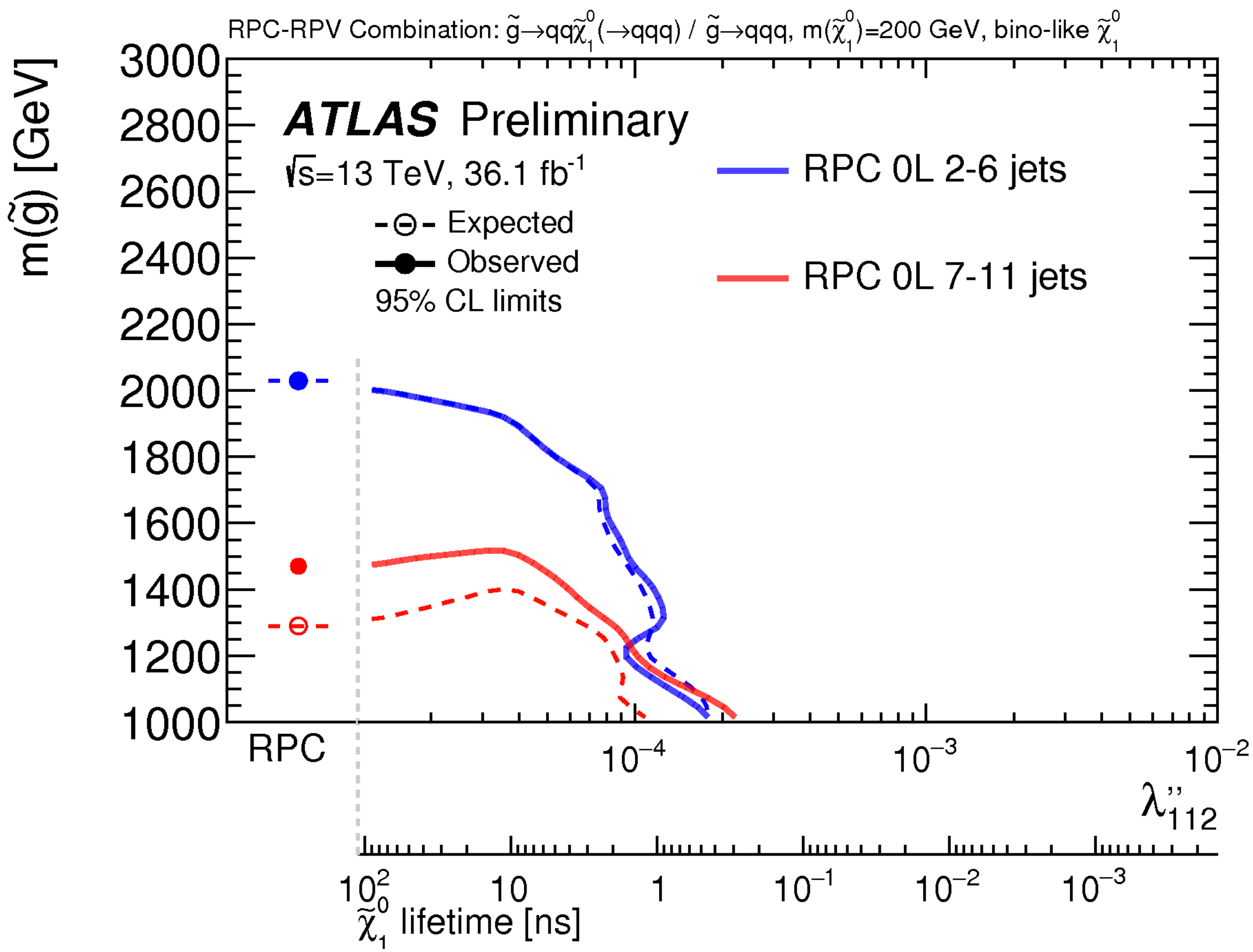


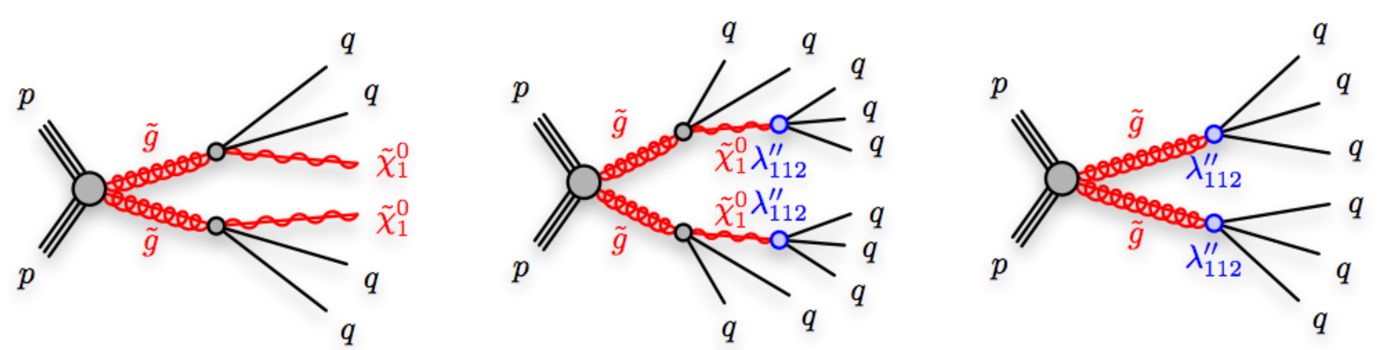


Turn on RPV coupling => jet multiplicity increases

E_T^{miss} reduction as LSP lifetime falls. E.g. 7 — 11 jets has no explicit E_T^{miss} cut

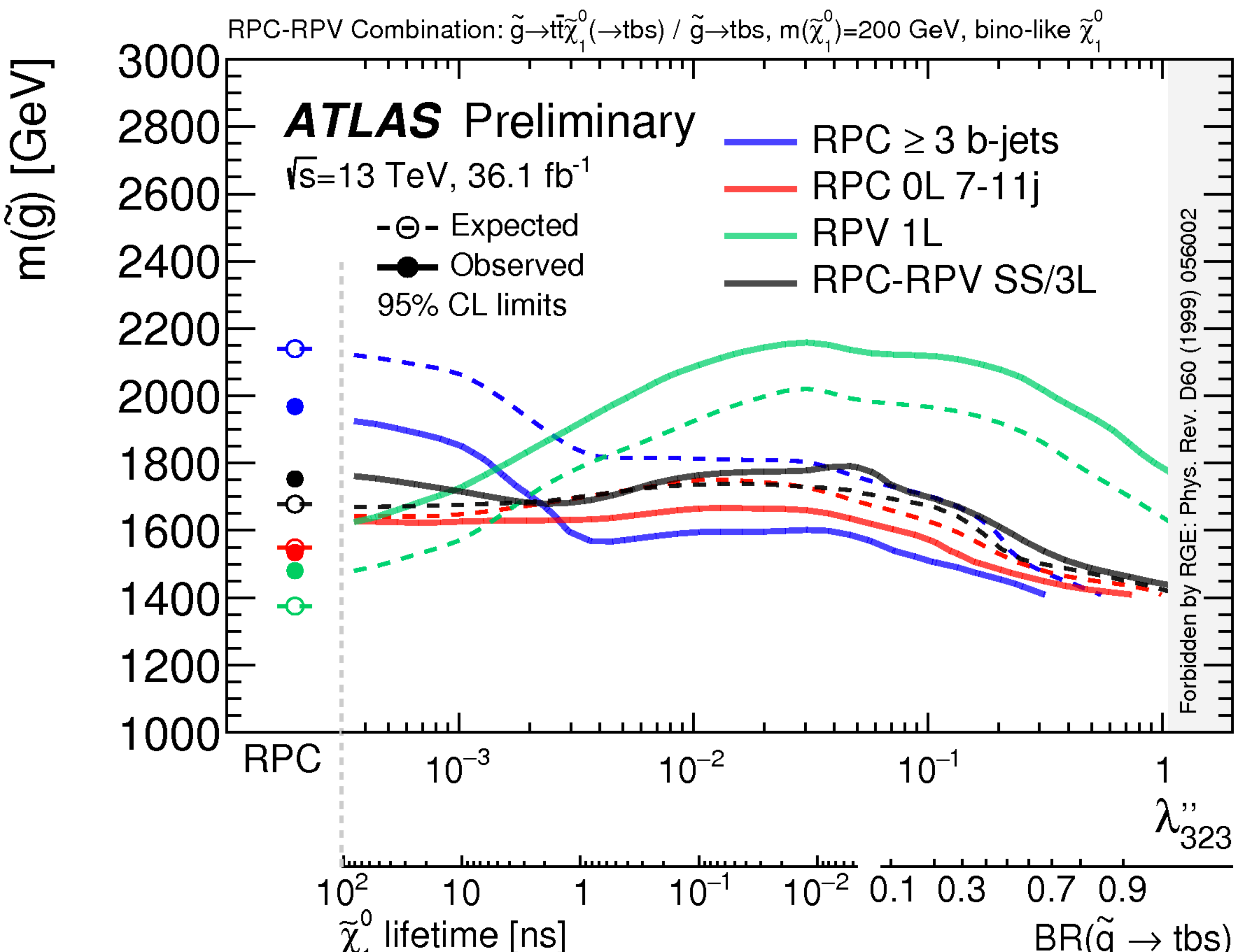
Gluino Sensitivity: *Gqq*

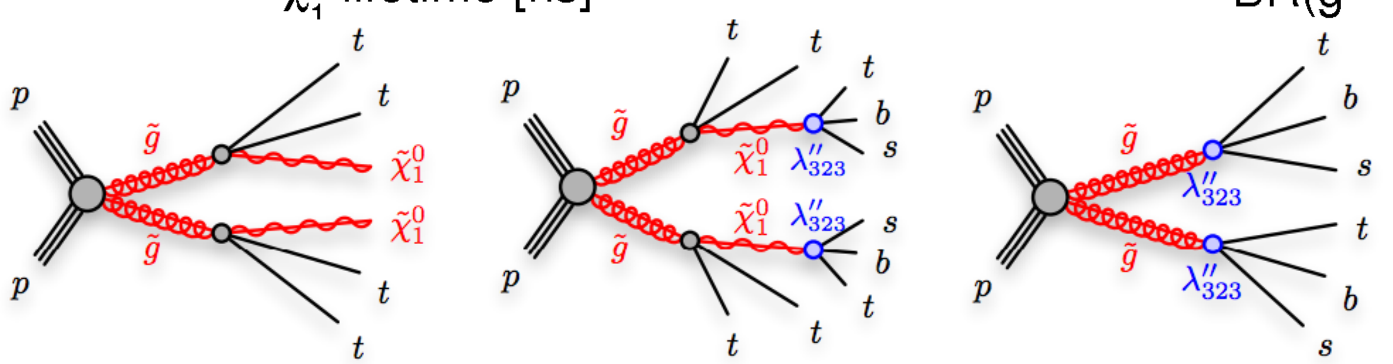




- Observed and expected limits on gluino mass, as a function of LSP lifetime, and the equivalent RPV coupling strength.
- 0L 2-6 sets strongest limits.
- Less competitive limits set by 7 — 11 jets, given moderate jet multiplicity of the signal.
- **Larger coupling => reduced LSP lifetime => E_T^{miss} reduced, and sensitivity falls.**

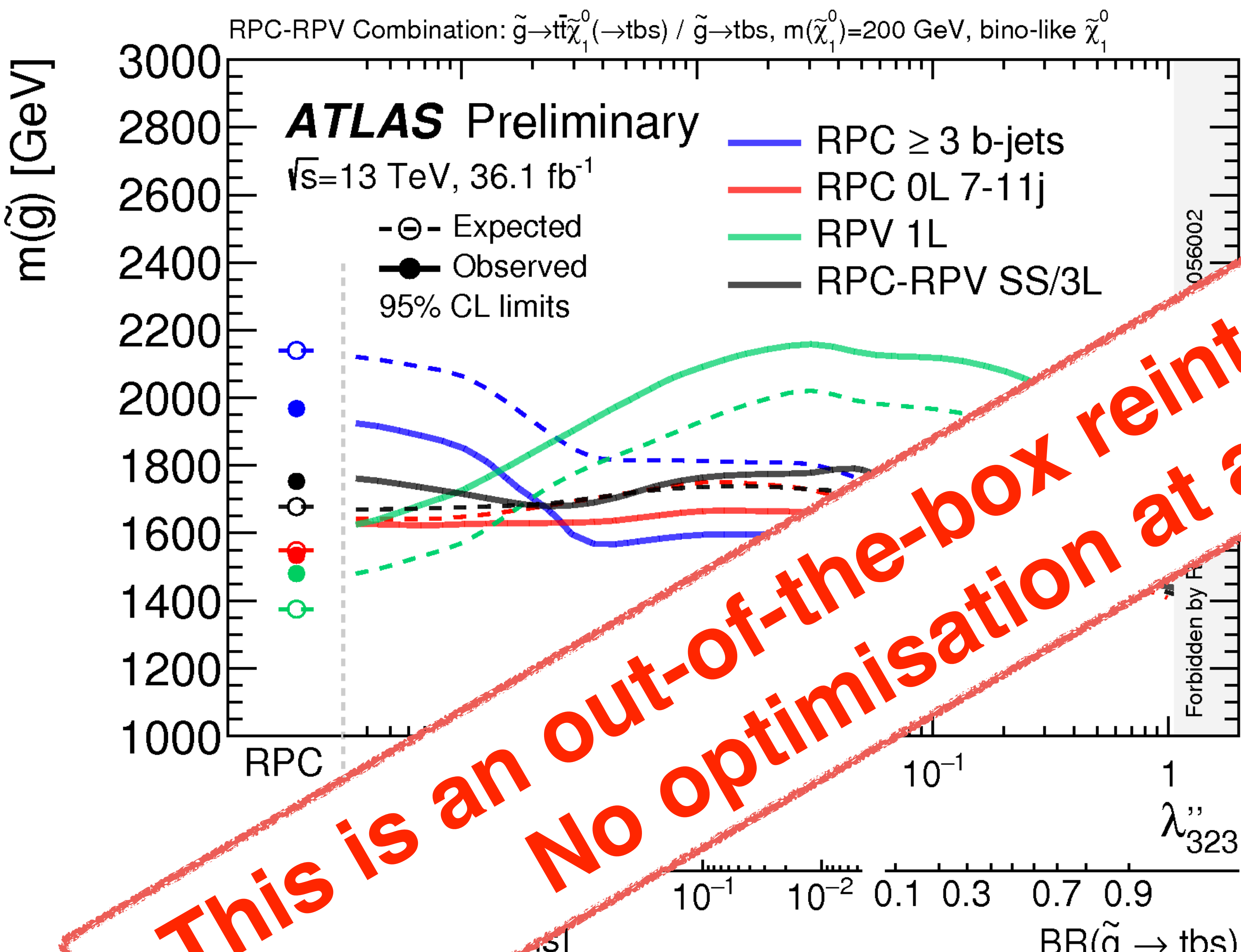
Gluino Sensitivity: *Gtt*



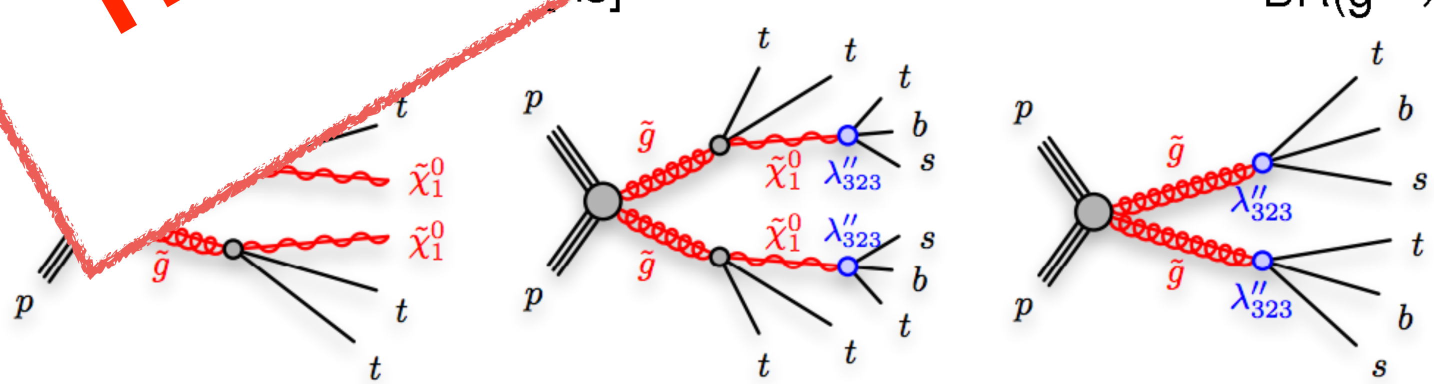


- Observed and expected limits on gluino mass, as a function of LSP lifetime, gluino branching ratio, and the equivalent RPV coupling strength.
- **Sets consistent limits across the RPV coupling.**
- Use of jet reclustering and *b*-tagging techniques, and moderate E_T^{miss}.

Gluino Sensitivity: *Gtt*

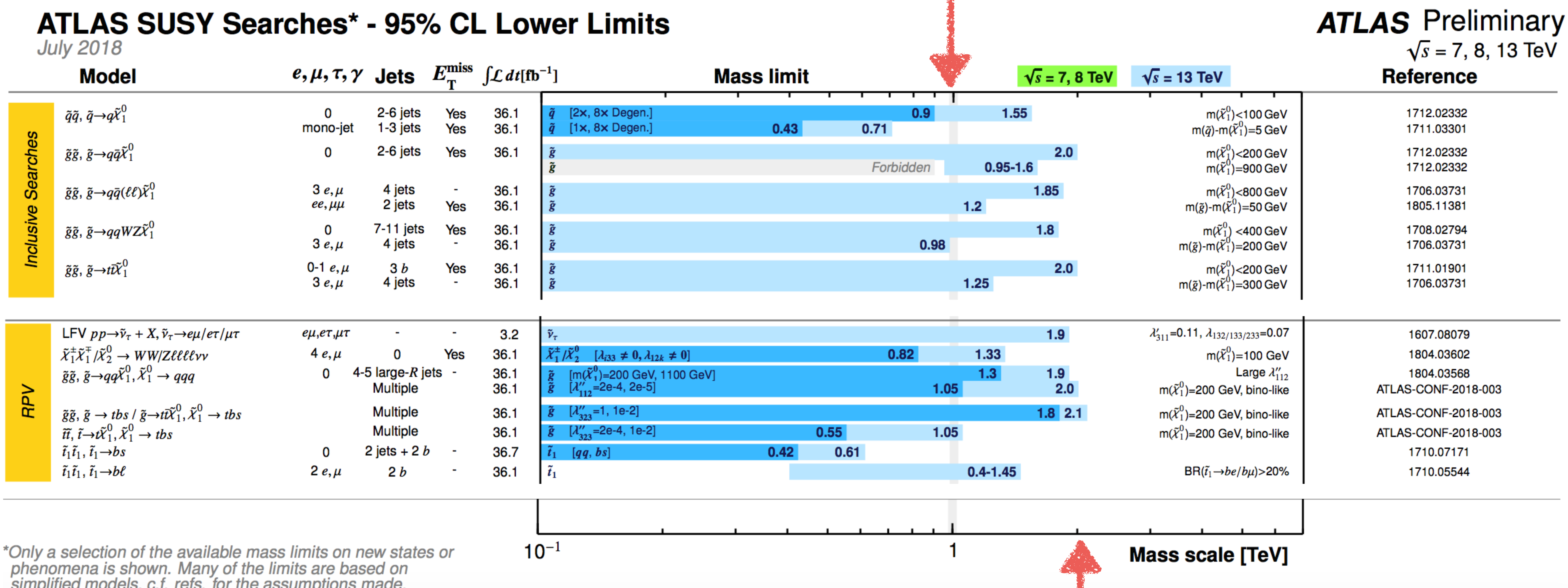


This is an out-of-the-box reinterpretation.
No optimisation at all :-)



- C... ...pected ... mass, as ... LSP lifetime, ... branching ratio, ... the equivalent RPV coupling strength.
- **Sets consistent limits across the RPV coupling.**
- Use of jet reclustering and *b*-tagging techniques, and moderate E_T^{miss}.

1 TeV



2 TeV

Full summary of results **here**

Summary

- It is possible to **reinterpret** searches for “conventional”, RPC SUSY in models of RPV SUSY.
- In addition ATLAS also has very nice new results for dedicated RPV searches since SUSY2017 last December.
- RPC and RPV are connected by the **RPV coupling strength** => can investigate the analysis sensitivity to the RPV SUSY continuum.
- In general, conventional and less conventional searches for gluinos are pushing limits on the **gluino mass above 2.0 TeV**.
- Limits on squarks are being pushed well **above 1.2 TeV, and up to 1.8 TeV** in the latest results (no time for details today, unfortunately !)

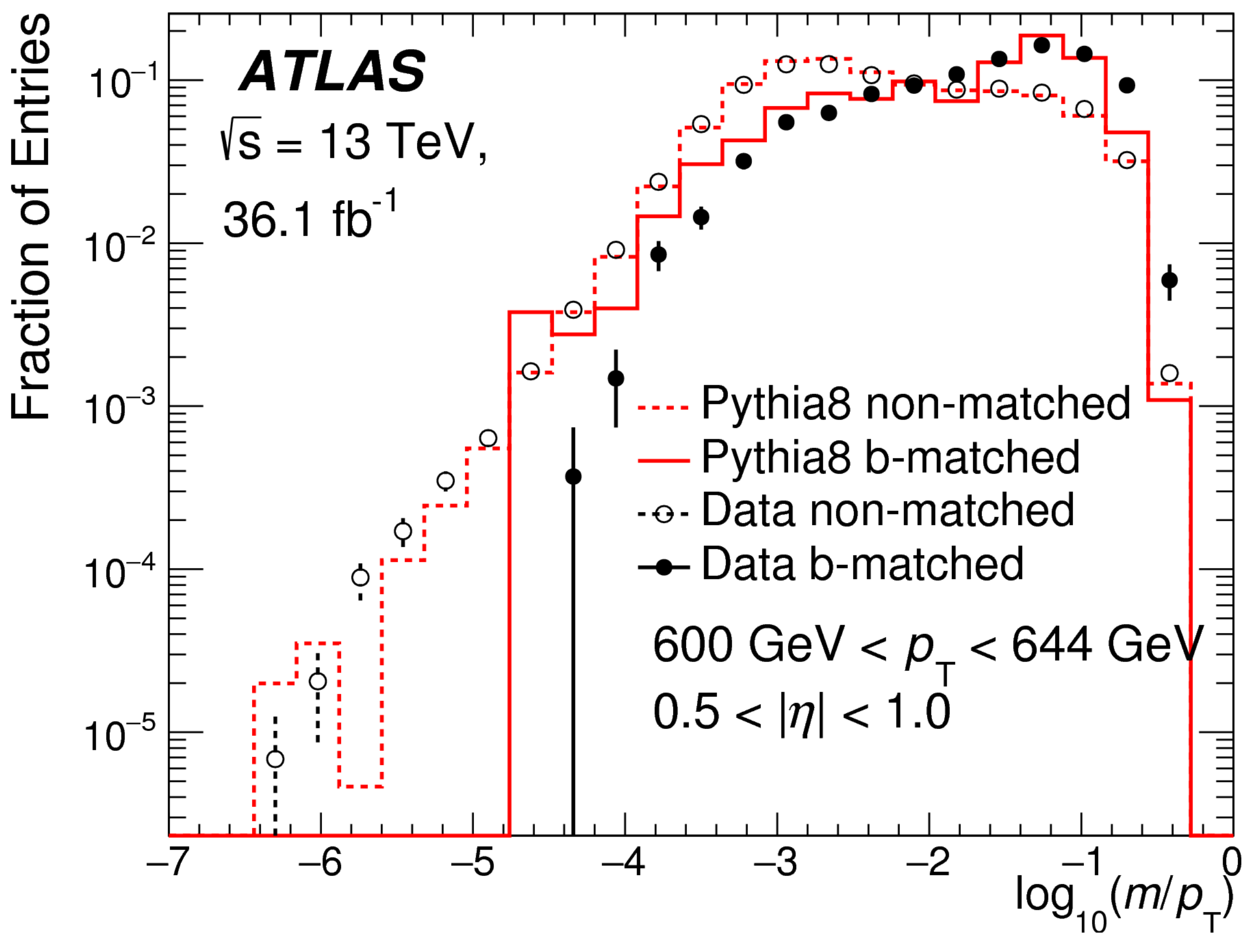
Backup

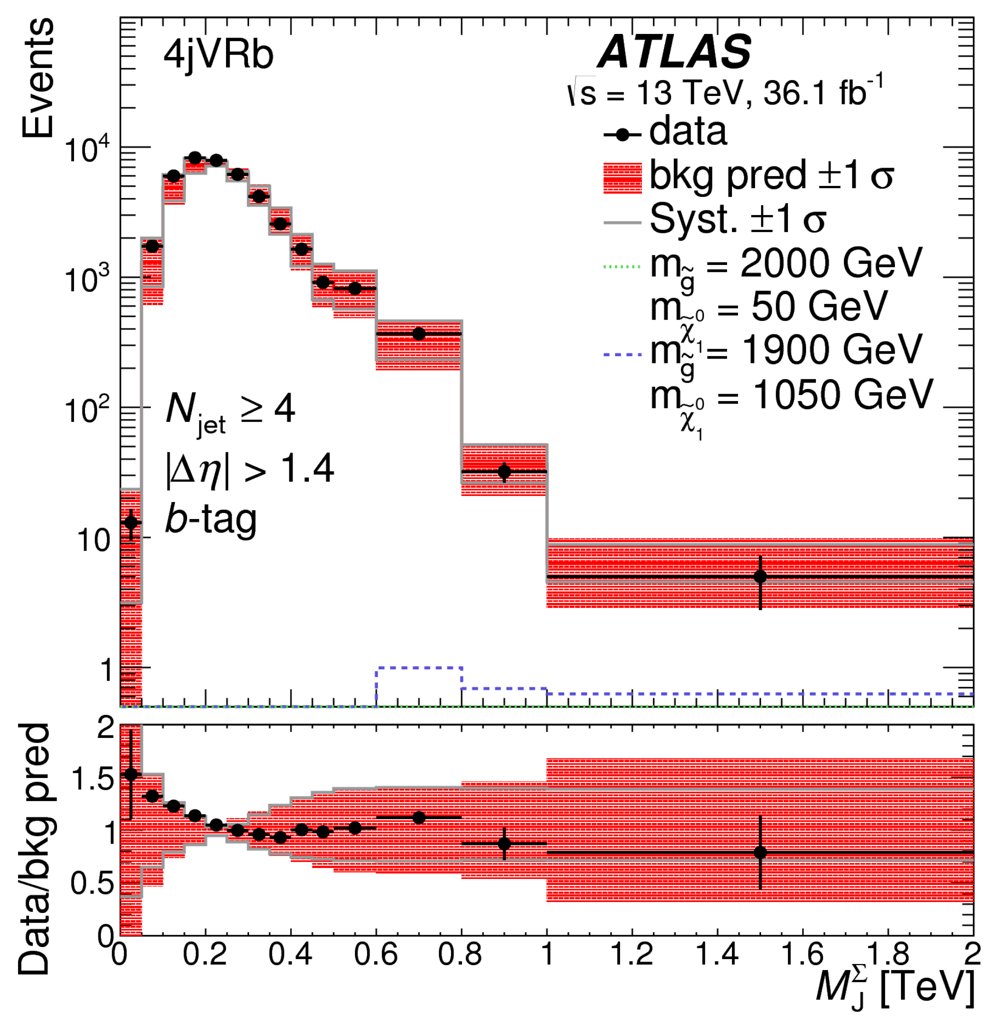
RPV Search with Multi-Jets: Region Summary

		n_{jet} ($p_{\text{T}} > 200$ GeV)	b-tag	$p_{\text{T},1}$	$\lvert\Delta\eta_{12}\rvert$	M_{J}^{Σ}
CR	3jCR	$= 3$	-	-	-	-
UDR	UDR1	$= 2$	-	> 400 GeV	-	-
	UDR2	$= 4$	-	< 400 GeV	-	-
VR	4jVR	≥ 4	-	> 400 GeV	> 1.4	-
	5jVR	≥ 5	-	-	> 1.4	-
	4jVRb	≥ 4	Yes	> 400 GeV	> 1.4	-
	5jVRb	≥ 5	Yes	-	> 1.4	-
SR	4jSR	≥ 4	-	> 400 GeV	< 1.4	> 1.0 TeV
	5jSR	≥ 5	-	-	< 1.4	> 0.8 TeV
	4jSRb	≥ 4	Yes	> 400 GeV	< 1.4	> 1.0 TeV
	5jSRb_1	≥ 5	Yes	-	< 1.4	> 0.8 TeV
	5jSRb_2	≥ 5	Yes	-	< 1.4	> 0.6 TeV

RPV Search with Multi-Jets: Template Method

- Template == Calculated **jet mass PDFs**, parameterised in jet p_T and $|\eta|$. Create template from a **controlled sample of background events**.
- Jet mass template used to generate a random mass, gradually building up a background M_J^Σ distribution of **randomised jet masses**.
- The predicted M_J^Σ distribution is **normalised to the observed 200 TeV < M_J^Σ < 600 TeV** (signal contamination negligible to statistical uncertainty).





RPV Search with Multi-Leptons: Region Summary

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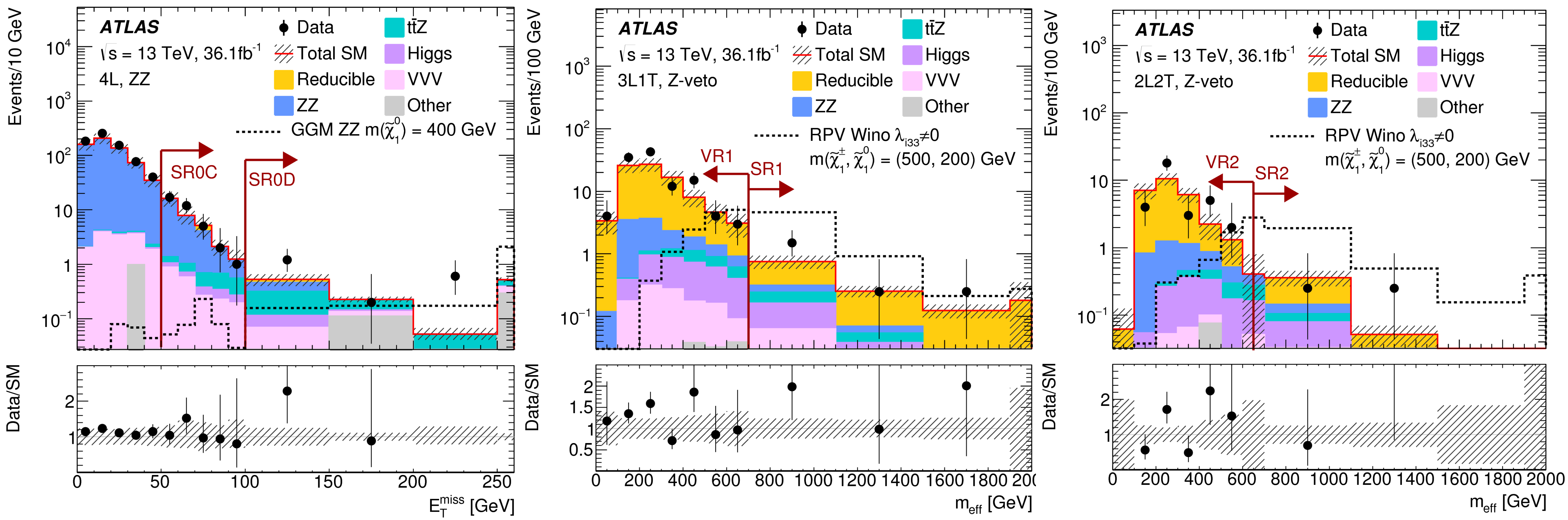
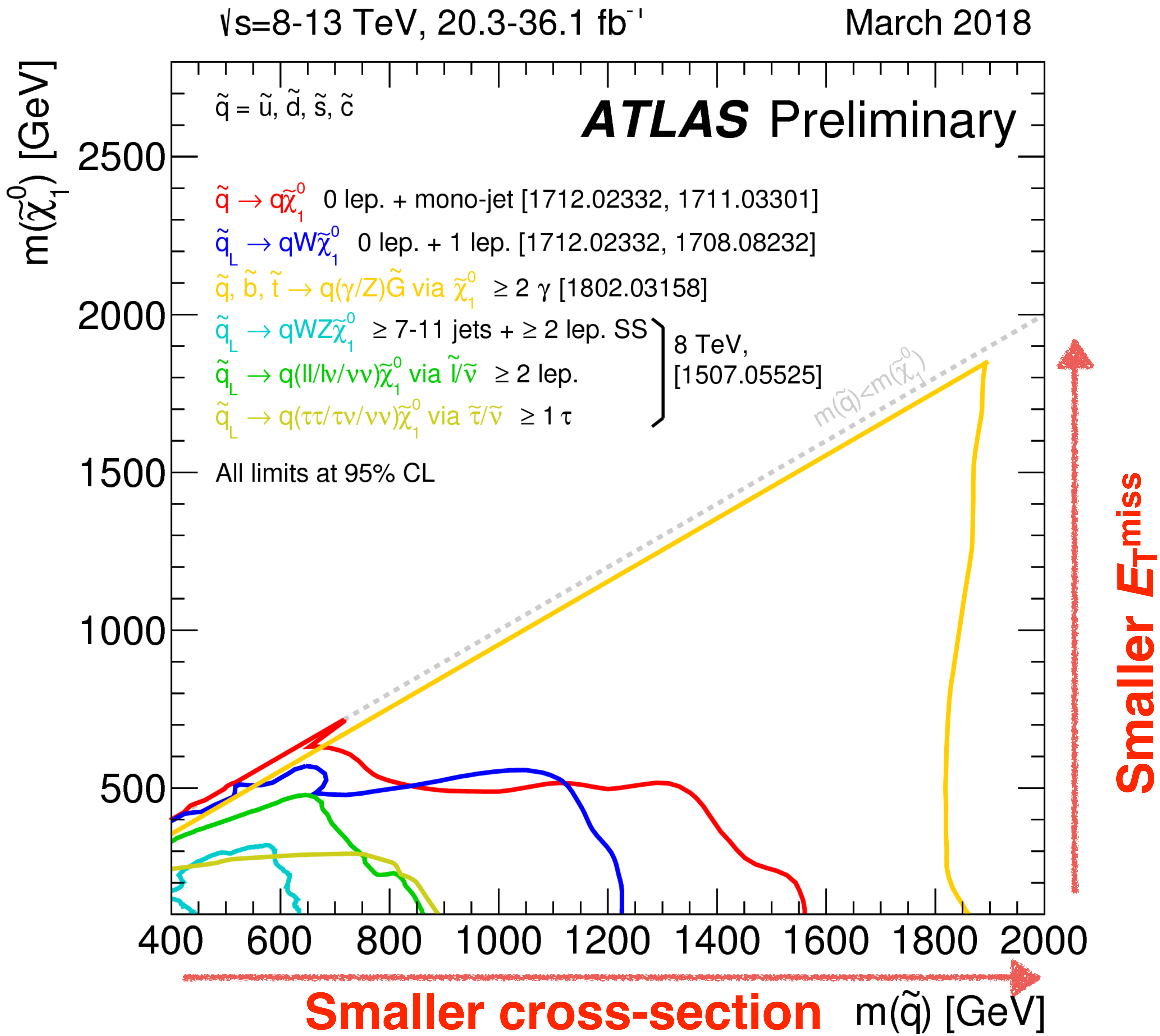
Region	$N(e,\mu)$	$N(\tau_{\text{had-vis}})$	$p_T(\tau_{\text{had-vis}})$	Z boson	Selection	Target
SR0A	≥ 4	$= 0$	> 20 GeV	veto	$m_{\text{eff}} > 600$ GeV	General
SR0B	≥ 4	$= 0$	> 20 GeV	veto	$m_{\text{eff}} > 1100$ GeV	RPV $LL\bar{E}12k$
SR0C	≥ 4	$= 0$	> 20 GeV	require 1st & 2nd	$E_T^{\text{miss}} > 50$ GeV	higgsino GGM
SR0D	≥ 4	$= 0$	> 20 GeV	require 1st & 2nd	$E_T^{\text{miss}} > 100$ GeV	higgsino GGM
SR1	$= 3$	≥ 1	> 30 GeV	veto	$m_{\text{eff}} > 700$ GeV	RPV $LL\bar{E}i33$
SR2	$= 2$	≥ 2	> 30 GeV	veto	$m_{\text{eff}} > 650$ GeV	RPV $LL\bar{E}i33$

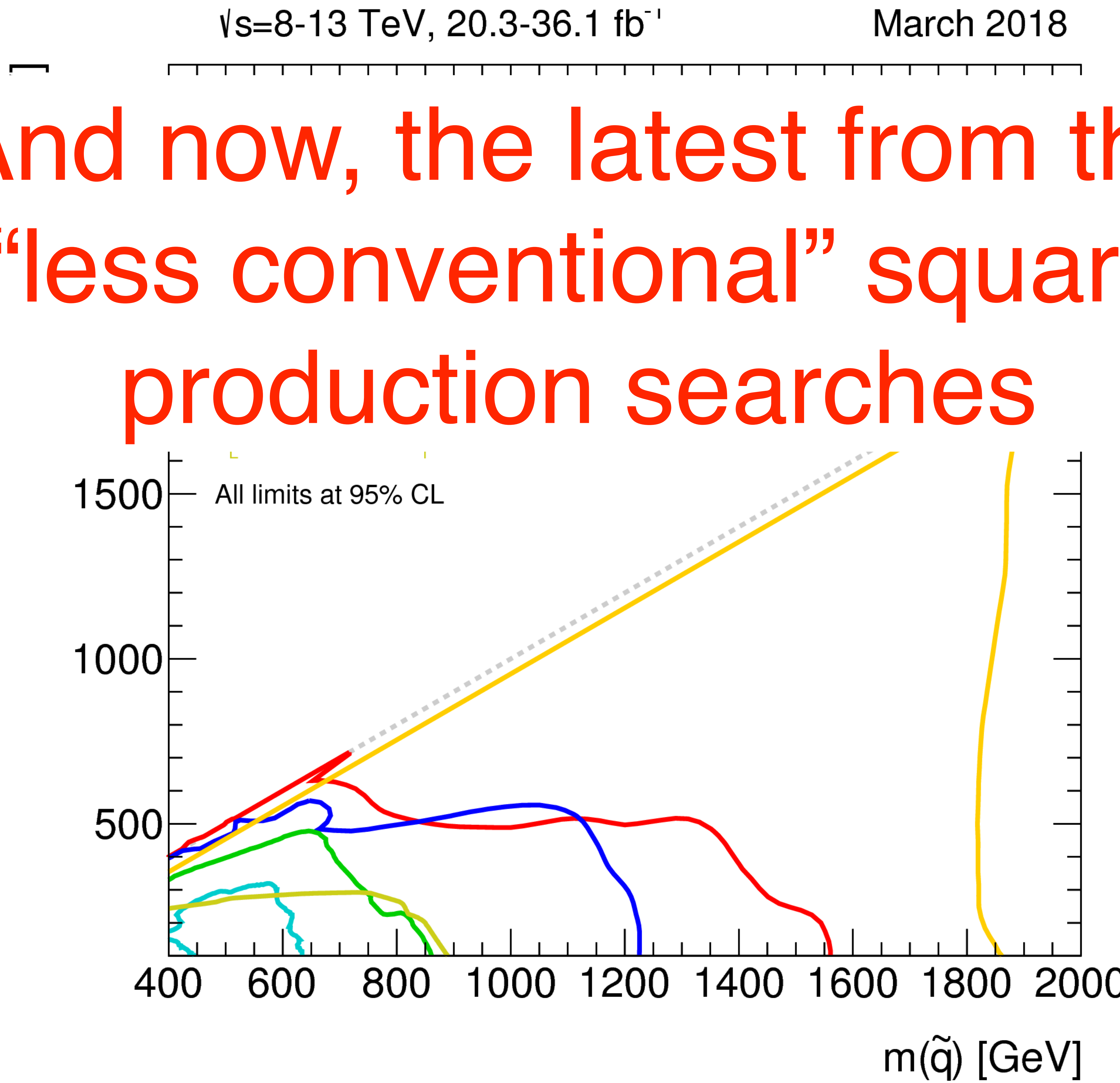
Reducible Estimation for	Control Region	$N(e,\mu)$ signal	$N(e,\mu)$ loose	$N(\tau_{\text{had-vis}})$ signal	$N(\tau_{\text{had-vis}})$ loose
$4L0T$	CR1_LLLl	$= 3$	≥ 1	$= 0$	≥ 0
	CR2_LLll	$= 2$	≥ 2	$= 0$	≥ 0
$3L1T$	CR1_LLLt	$= 3$	$= 0$	$= 0$	≥ 1
	CR1_LLTl	$= 2$	$= 1$	≥ 1	≥ 0
	CR2_LLlt	$= 2$	$= 1$	$= 0$	≥ 1
$2L2T$	CR1_LLTt	$= 2$	$= 0$	$= 1$	≥ 1
	CR2_LLtt	$= 2$	$= 0$	$= 0$	≥ 2

RPV Search with Multi-Leptons: More SR Kinematics



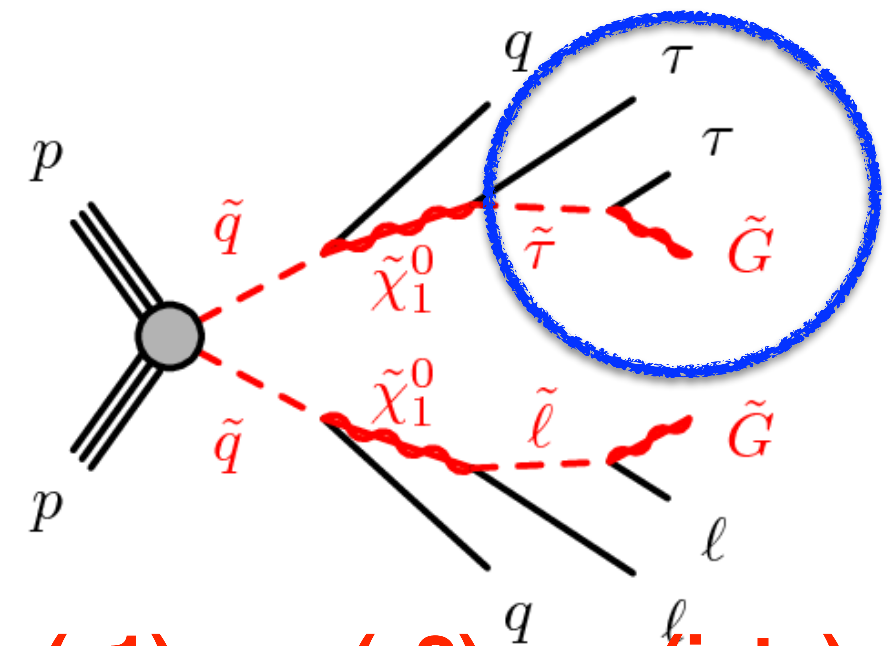

√s=8-13 TeV, 20.3-36.1 fb⁻¹
March 2018
q̃ = ũ, d̃, s̃, c̃
ATLAS Preliminary
q̃ → qχ̃⁰₁ 0 lep. + mono-jet [1712.02332, 1711.03301]
q̃L → qWχ̃⁰₁ 0 lep. + 1 lep. [1712.02332, 1708.08232]
q̃, b̃, t̃ → q(γ/Z)G̃ via χ̃⁰₁ ≥ 2 γ [1802.03158]
q̃L → qWZχ̃⁰₁ ≥ 7-11 jets + ≥ 2 lep. SS
q̃L → q(ll/lν/νν)χ̃⁰₁ via l̃/ν̃ ≥ 2 lep.
q̃L → q(ττ/τν/νν)χ̃⁰₁ via τ̃/ν̃ ≥ 1 τ
8 TeV, [1507.05525]
All limits at 95% CL
m(q̃)<m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(q̃) [GeV]
Smaller cross-section
Smaller E_T^{miss}

And now, the latest from the “less conventional” squark production searches



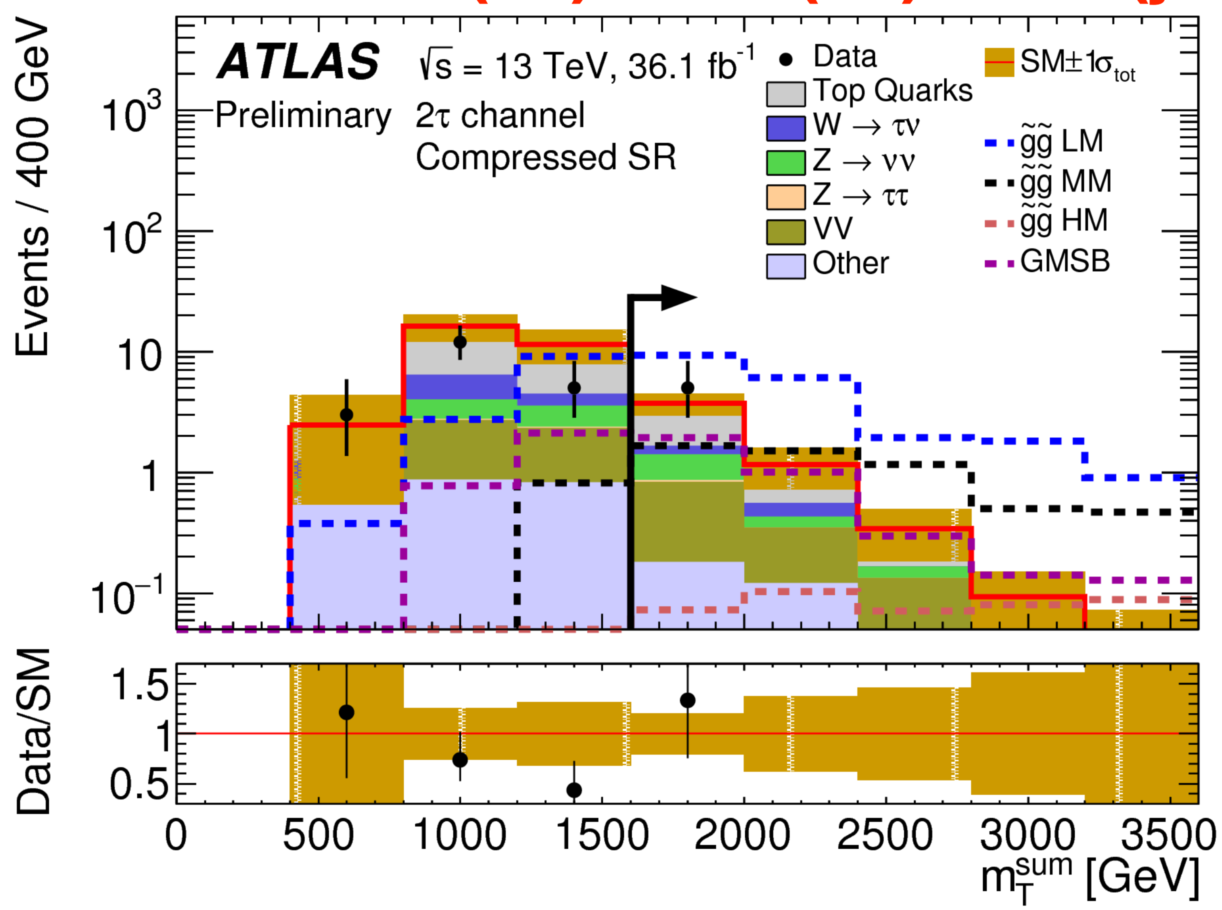
Catching Squarks and Gluinos with Taus

- Gauge-mediated symmetry breaking (GMSB) model => **scalar lepton is preferentially a stau** for high tanβ. More details in **SUSY-2016-03**

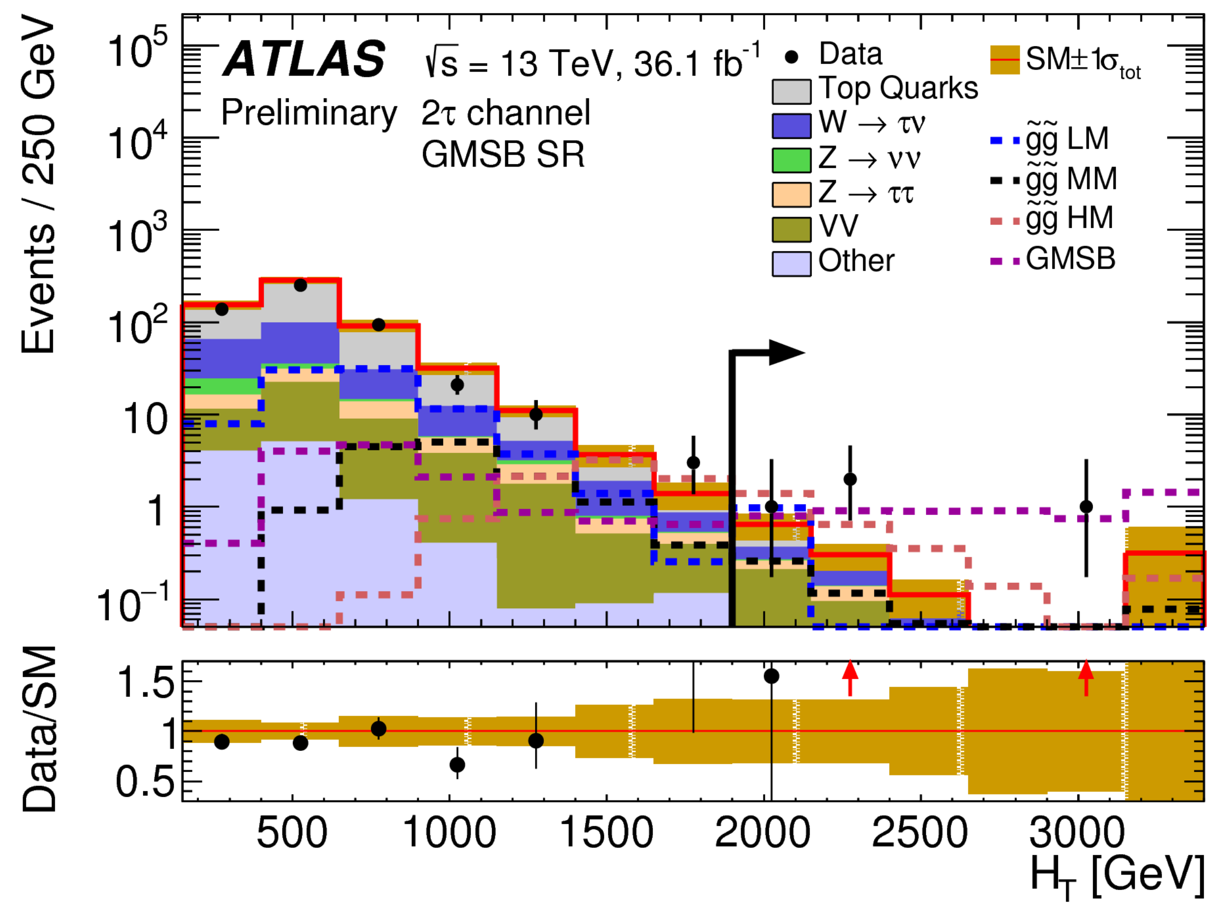


- Dedicated **1 and 2τ signal regions**, including optimisation for the compressed region, and control region for tau fakes from *W* decay.

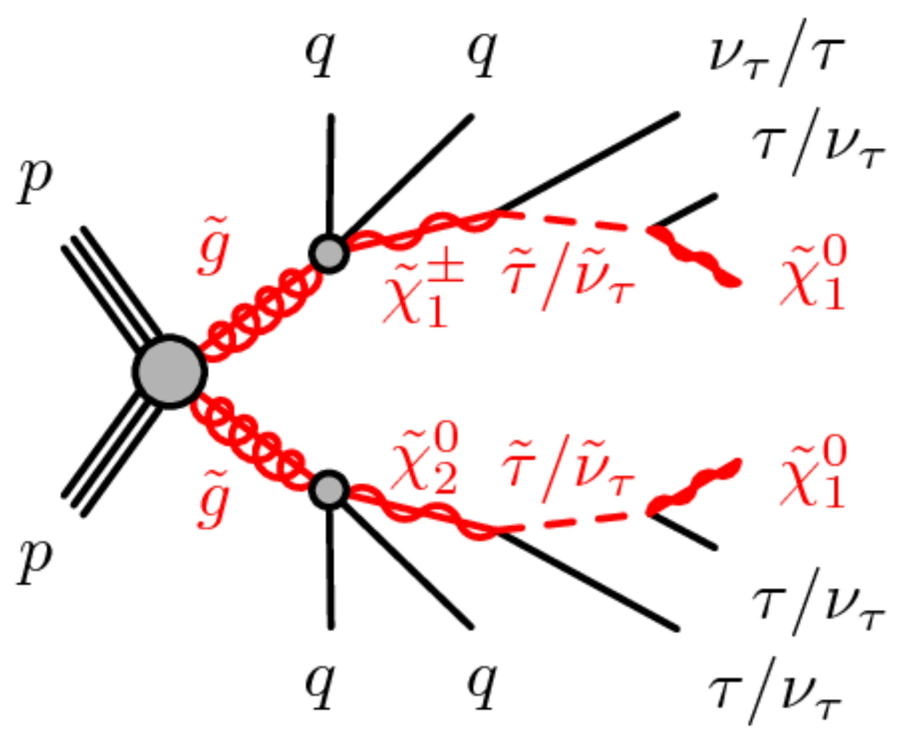
$m_T^{sum} = m_T(\tau 1) + m_T(\tau 2) + m_T(\text{jets})$

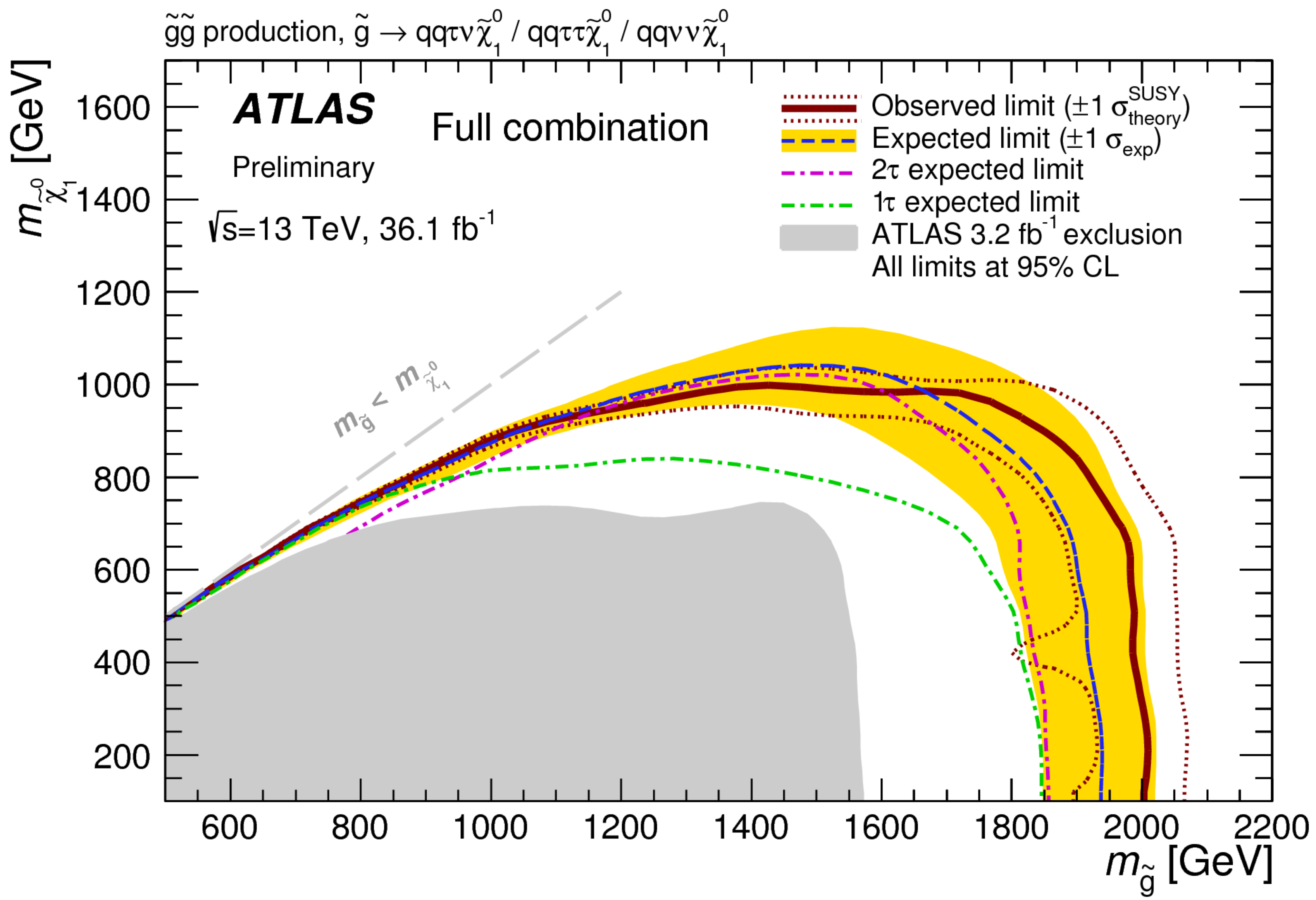


$H_T = p_T(\tau 1) + p_T(\tau 2) + p_T(\text{jets})$



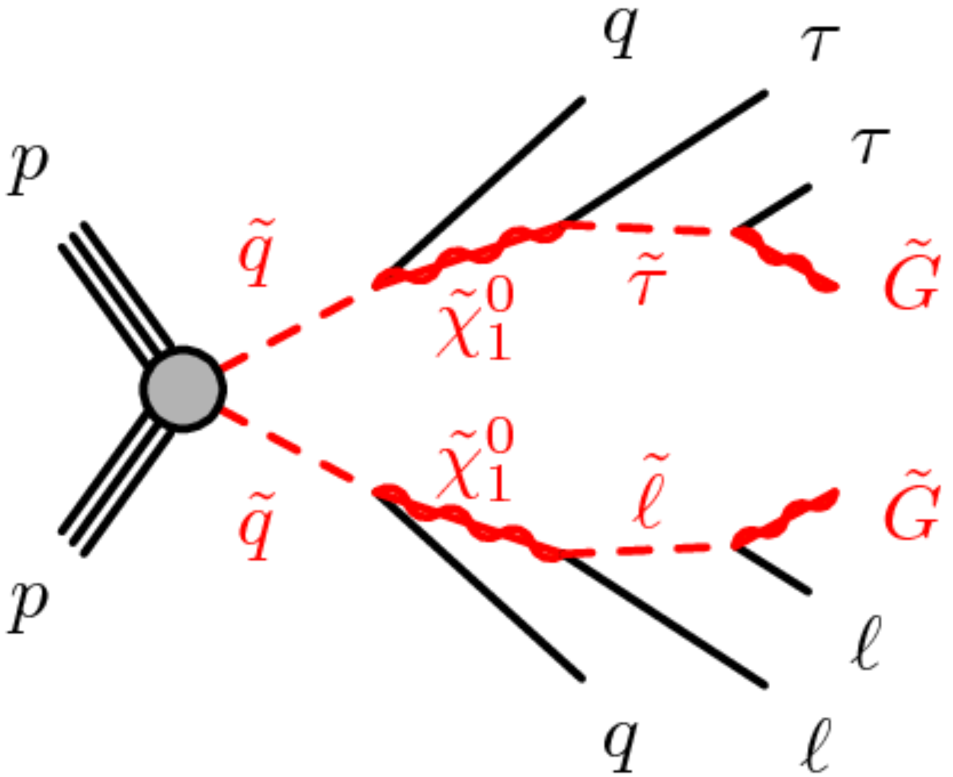
Catching Squarks and **Gluinos** with Taus

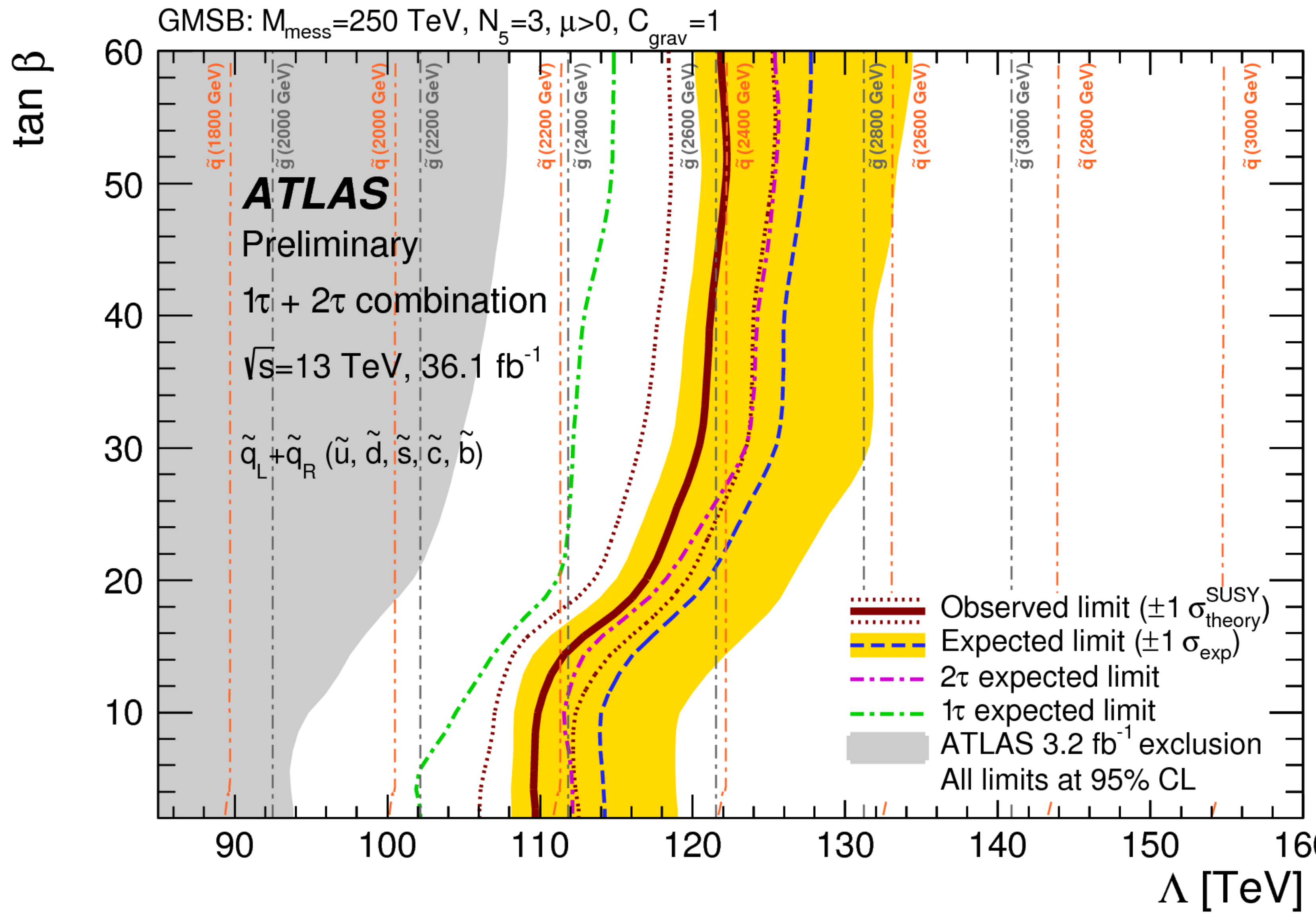




- **Pushing gluino sensitivity to 2.0 TeV !**
- Limit calculated from the **combination of the 1 and 2τ channels.**

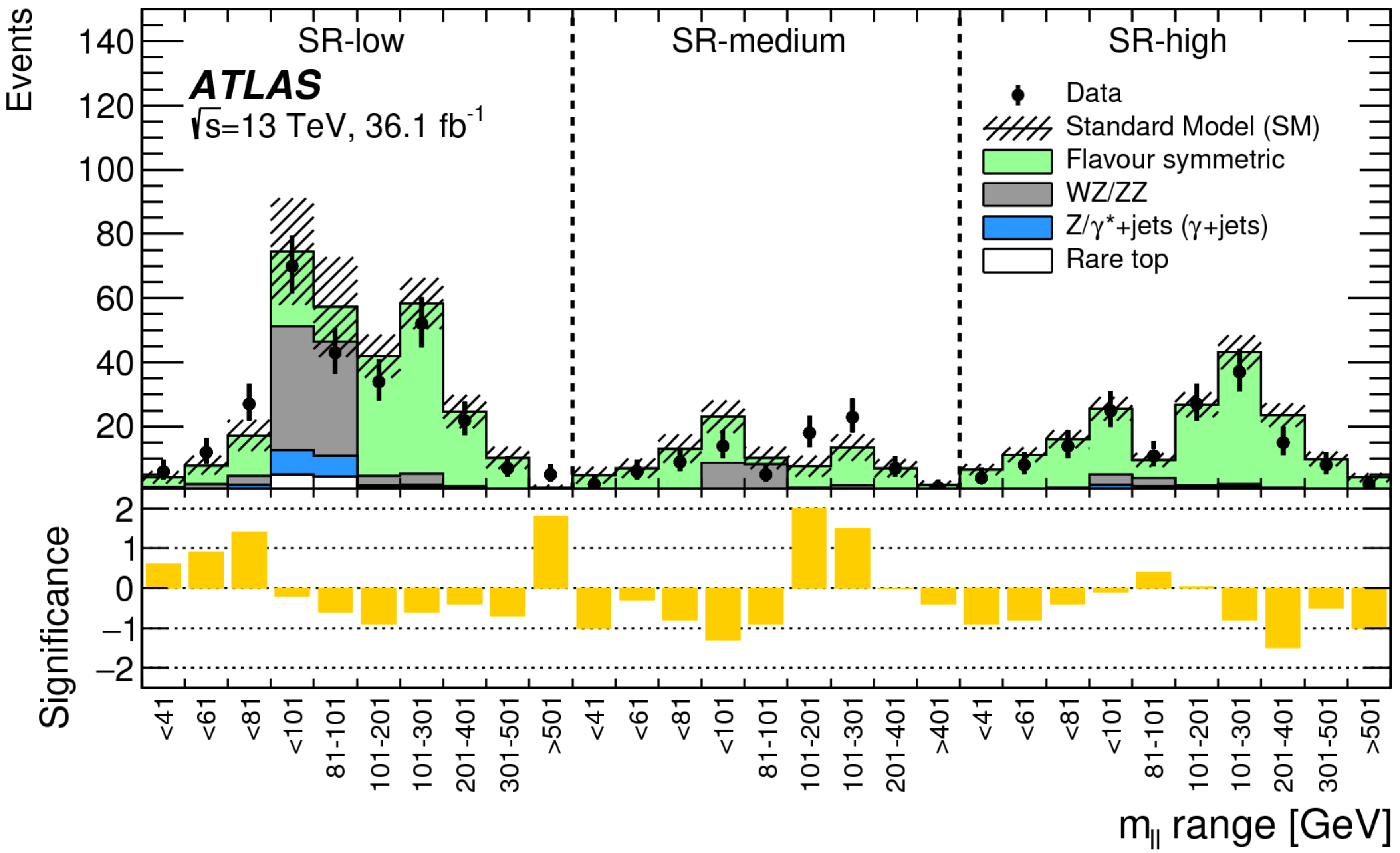
Catching **Squarks** and Gluinos with Taus

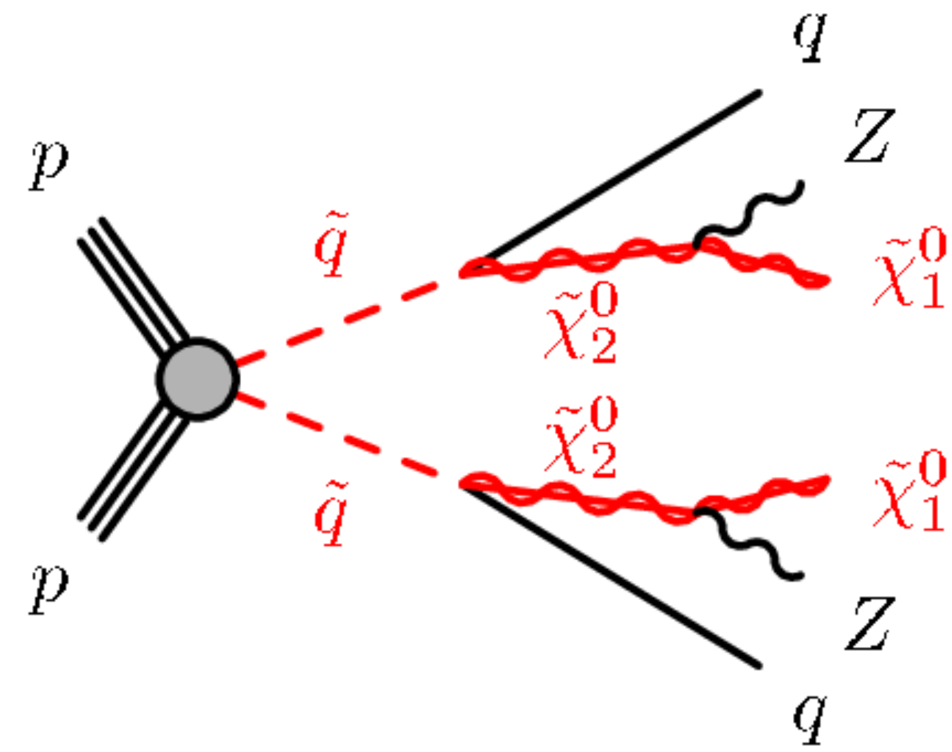




- Limit calculated from the **combination of the 1 and 2τ channels.**
- Significantly extending exclusions on the **SUSY-breaking mass scale, *Λ***, (assuming GMSB) for different **squark and gluino masses** (orange and grey dotted lines).

Catching Squarks with a Z edge

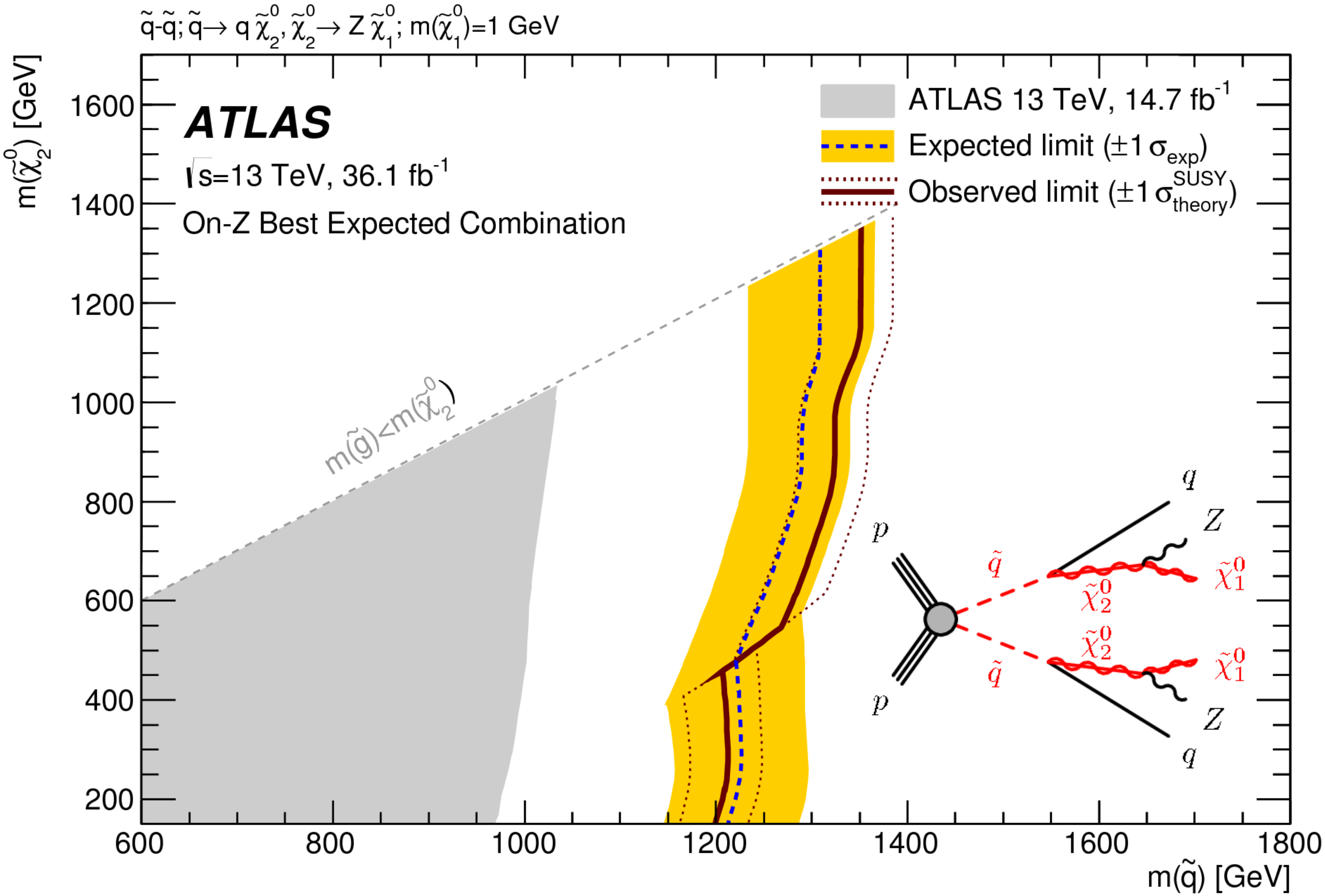




$\Delta m_\chi = m_{\chi 2} - m_{\chi 1}$

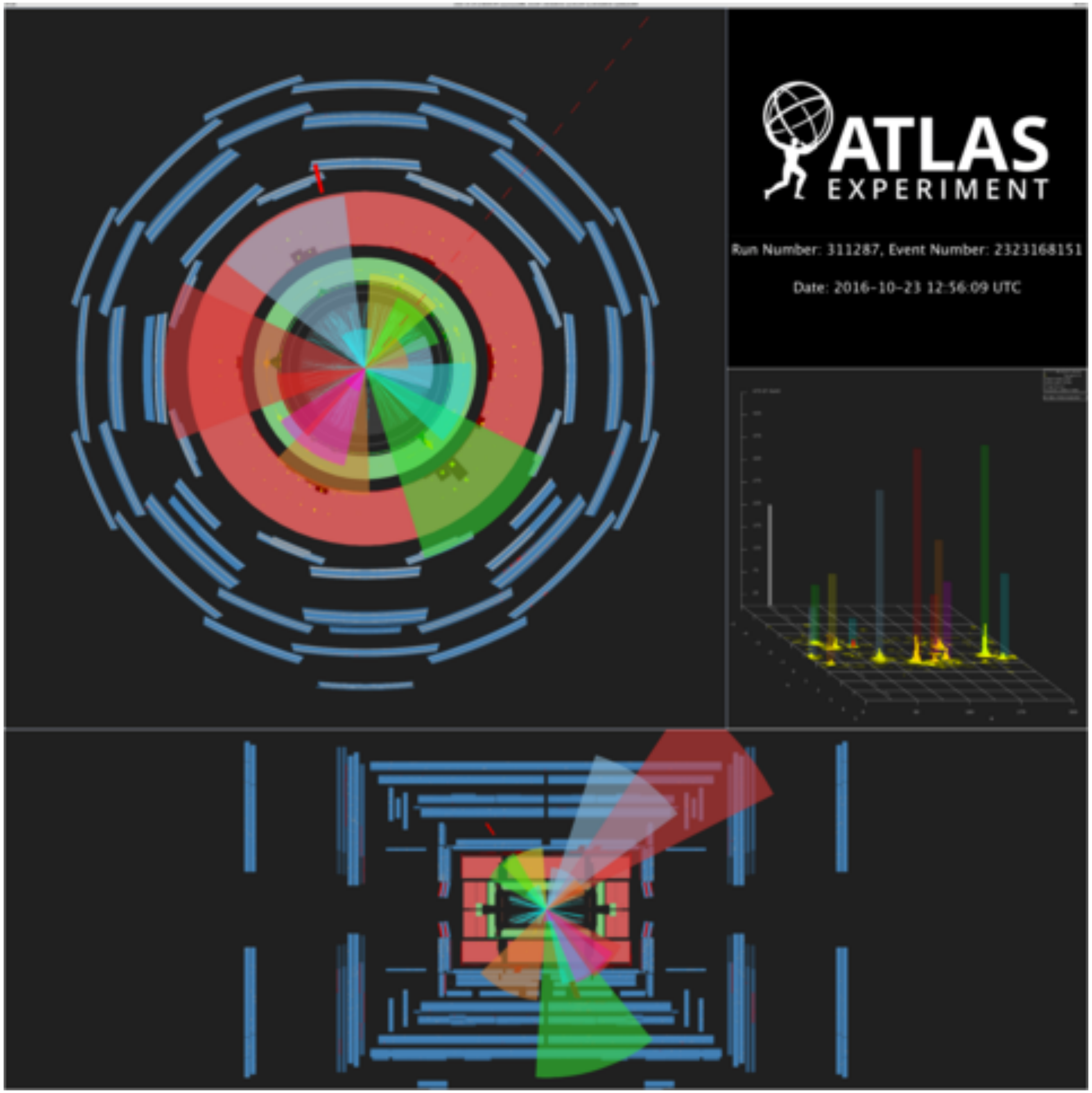
- $\Delta m_\chi < m_Z$: m_{ll} distribution can have a **kinematic endpoint ("edge")** at Δm_χ
- Search for an "edge" by **scanning in the $Z \rightarrow ee$ or $\mu\mu$ invariant mass**, using mass windows above and below the Z peak.
- More in **SUSY-2016-33**.

Catching Squarks with a *Z* edge



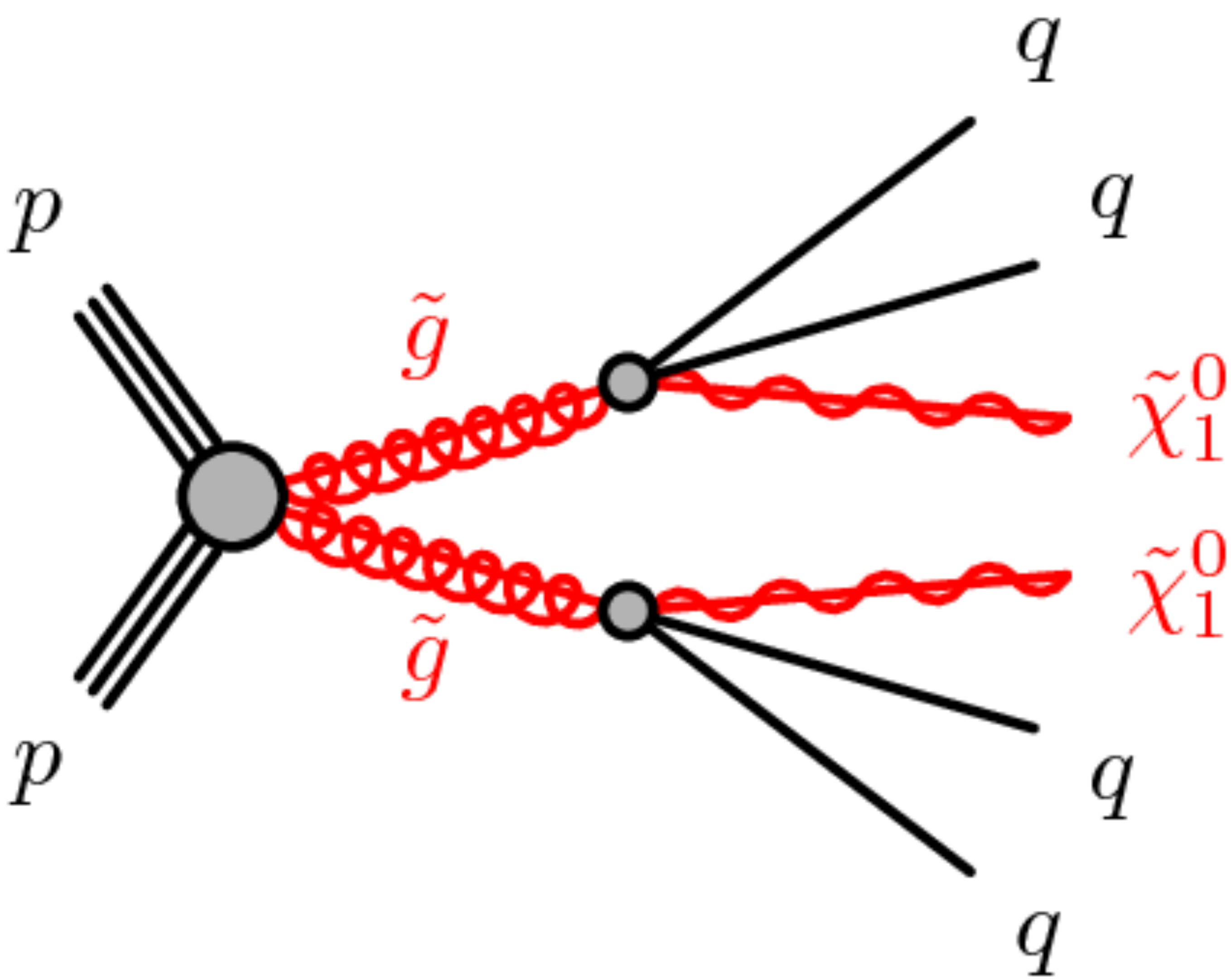
- Significant gain in sensitivity to **squark masses above 1.2 TeV**, with the full 2015 + 2016 ATLAS dataset.

Let's take jet multiplicity to the extreme …



13-jet event reconstructed in the ATLAS calorimeter !

A Picture of "Conventional" Supersymmetry (SUSY)



- Gluino (spin-1/2 SUSY partner of the gluon) production at the LHC.
- Decay cascade into SUSY and Standard Model (SM) particles.
- Cascade produces final state quarks => **hadronization into many jets**.
- Lightest SUSY particle (LSP) passes through ATLAS, undetected => **measure real missing transverse momentum** (E_T^{miss}).

Backgrounds and How to Control Them

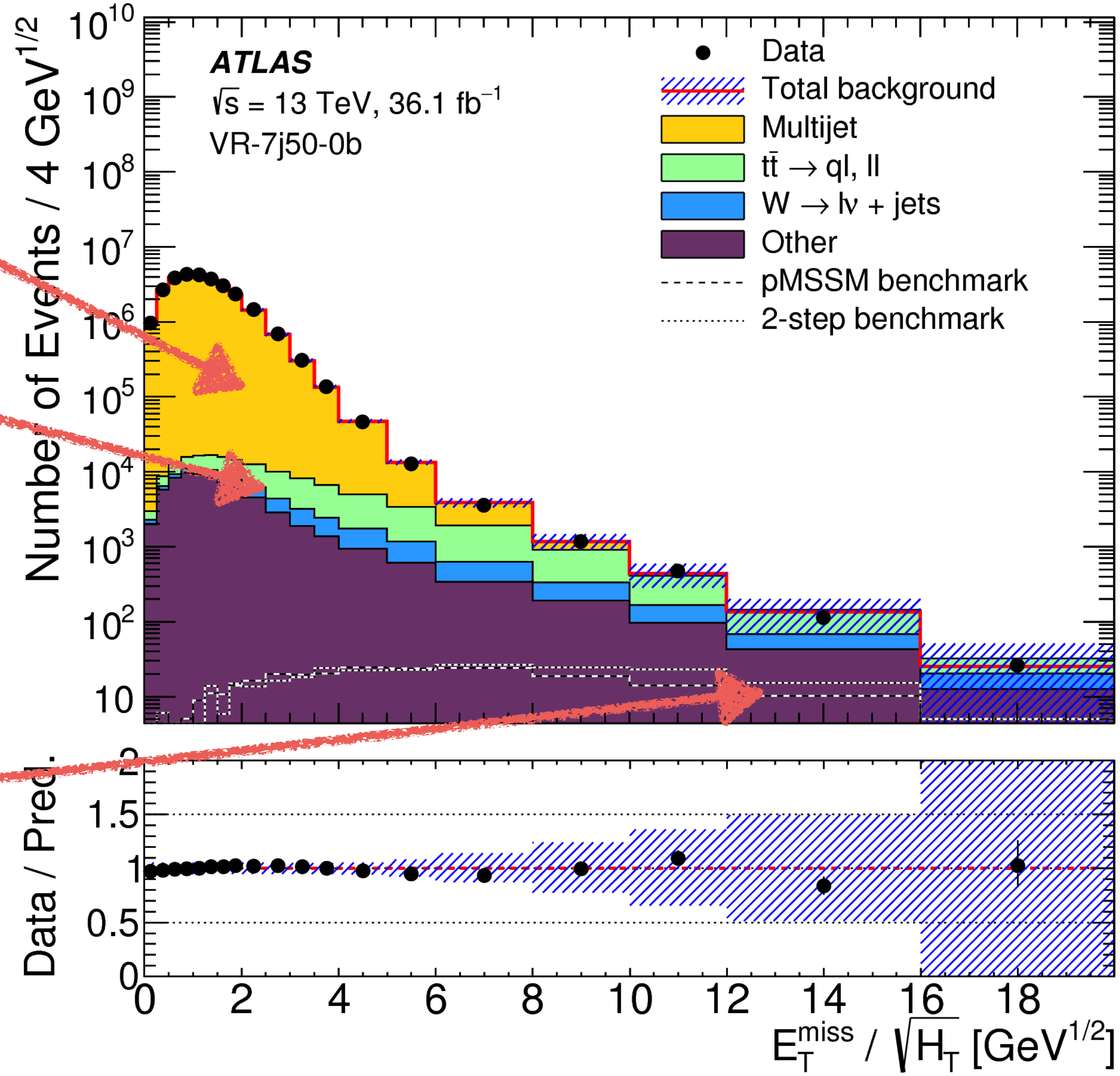
Major backgrounds:

- **Multi-jet background**: QCD multi-jets and fully-hadronic top production.
- **Leptonic backgrounds**.

Large multi-jet background at moderate E_T^{miss} significance.

Sufficiently large E_T^{miss} significance is our hunting ground for new physics.

The multi-jets background must be estimated using a fully data-driven approach … **the template method**.



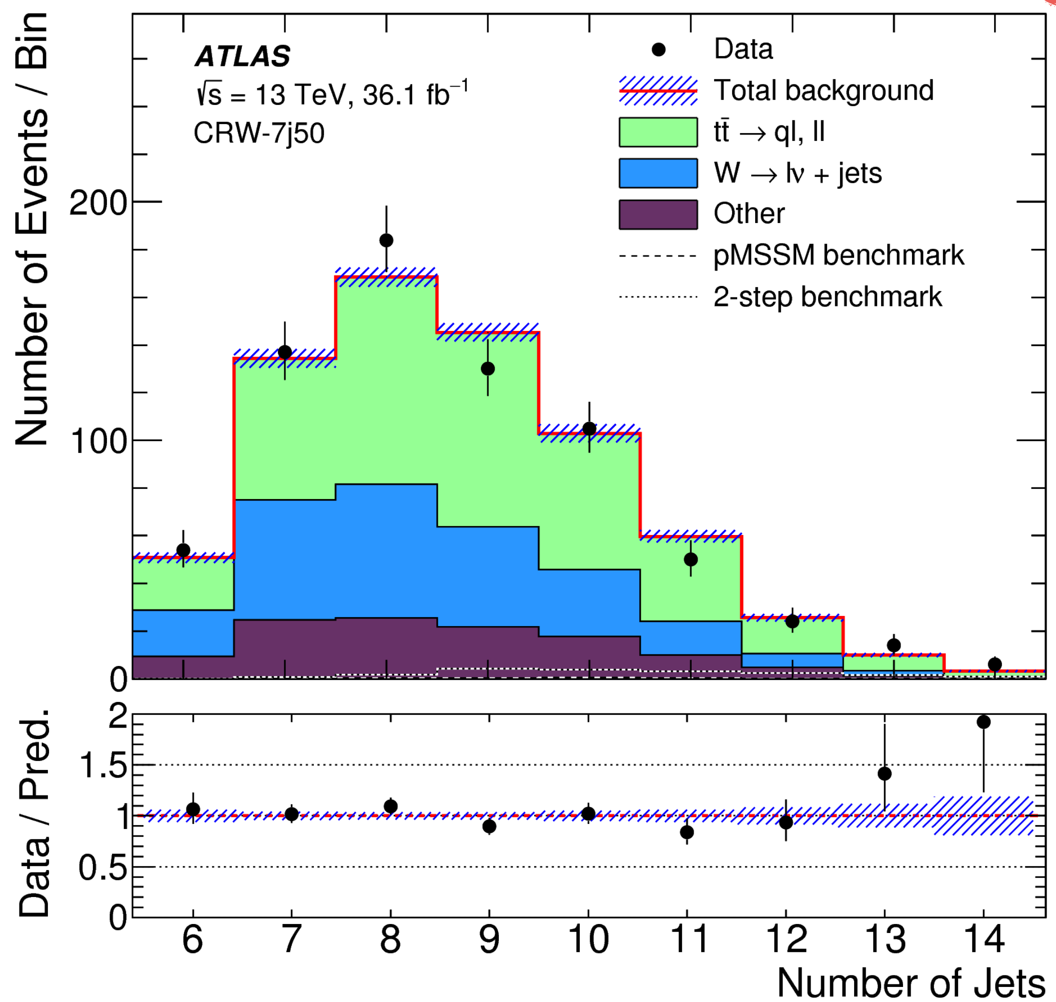
Backgrounds and How to Control Them

CRs for two largest Monte Carlo backgrounds: ***W* +jets and top production + jets,** constructed by **requiring zero and one inclusive *b*-jet respectively.**

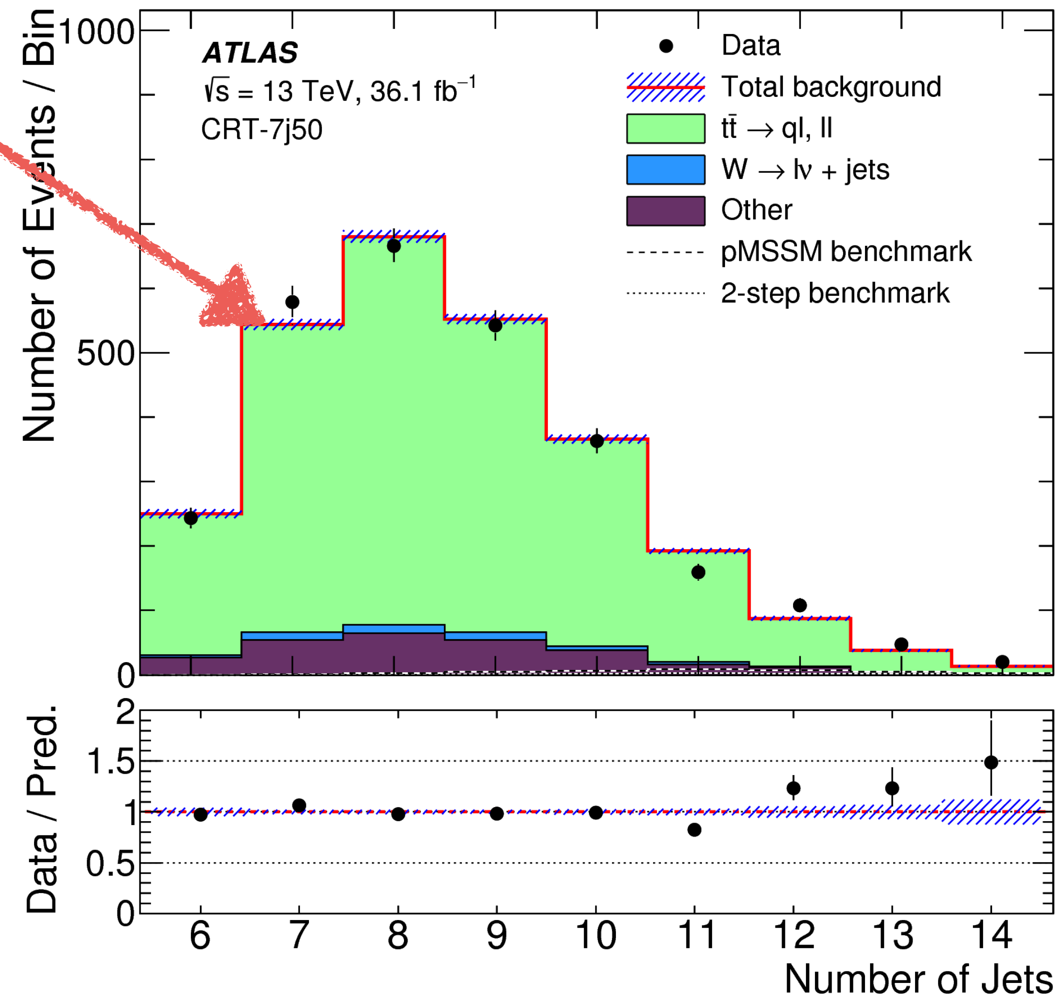
For each N_{jet} SR of jet multiplicity N_{jet}, an **N_{jet}-1 CR** is calculated for the *W*+jets and hadronic top backgrounds.

These CRs provide normalisations to the yields from the **largest MC backgrounds**.

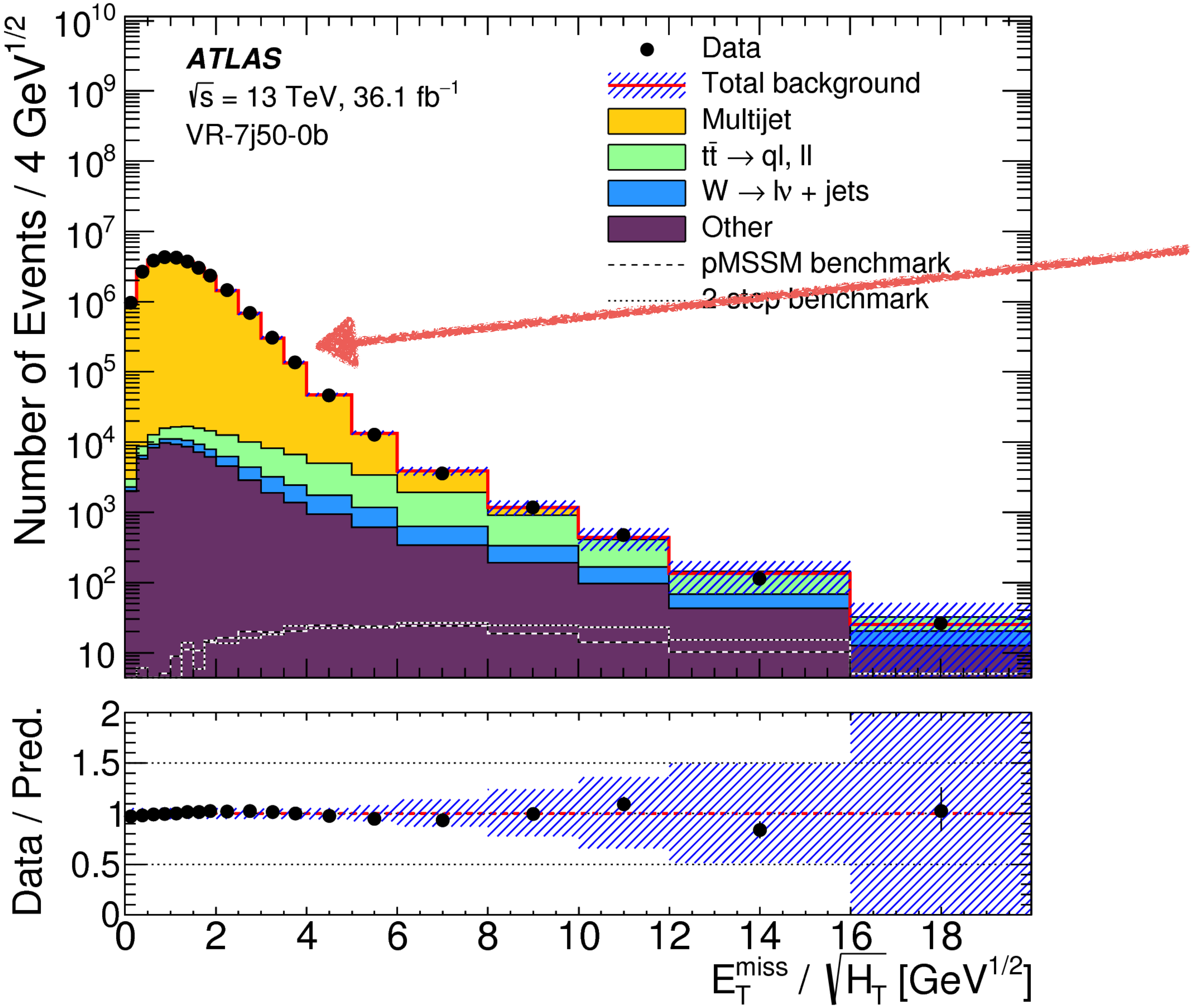
W+jets CR



Top CR



The Template Method



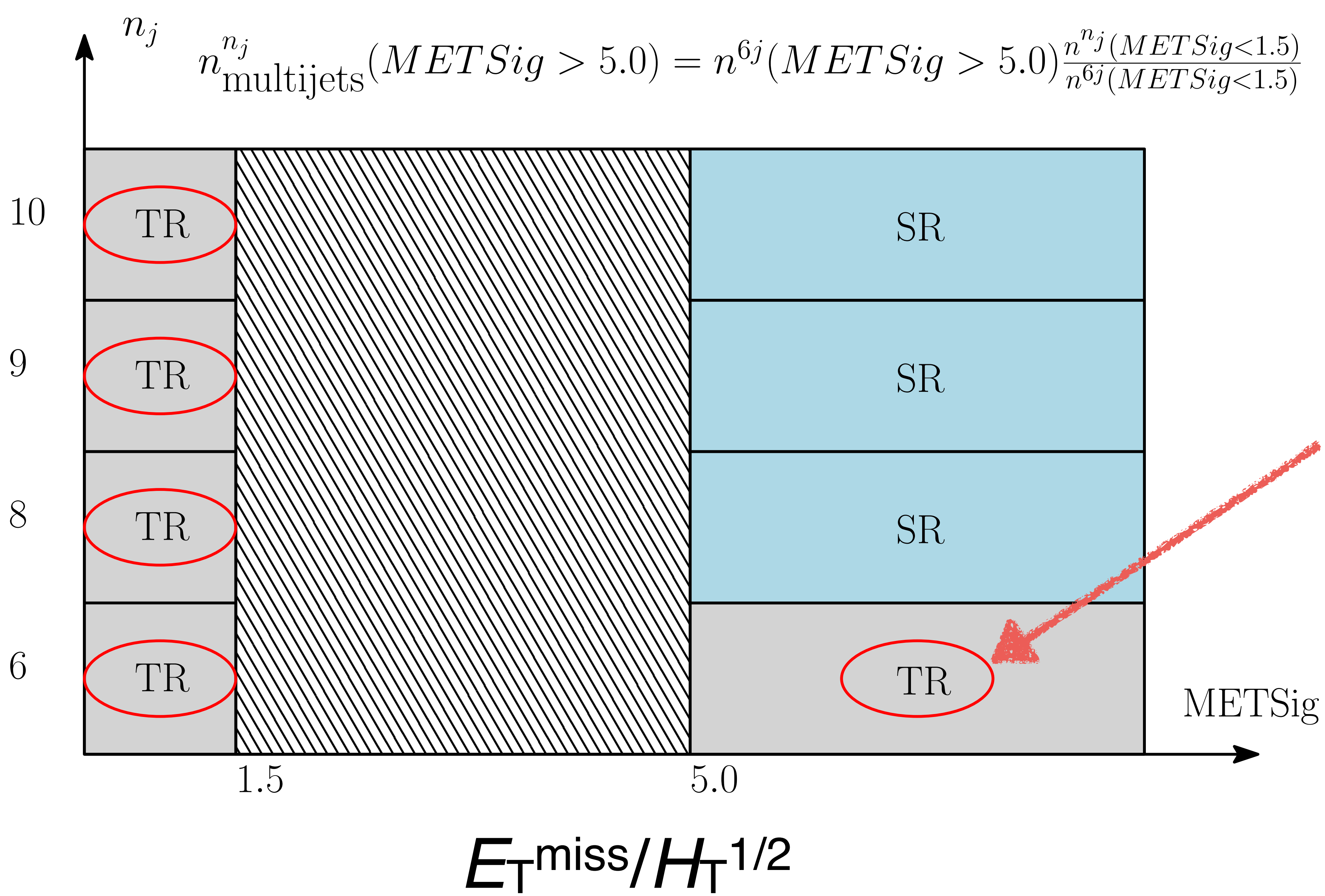
Fully data-driven multi-jet background estimation.

E_T^{miss} significance shape is **approximately invariant** under different (high) jet multiplicities.

Calculate the multi-jet contribution in the 6-jet, E_T^{miss} significance > 5 GeV$^{1/2}$ **template region**.

Rescale the shape in each of the signal regions by considering the relative change in size of the multi-jet dominated peak at **E_T^{miss} significance < 1.5 GeV$^{1/2}$**.

The Template Method



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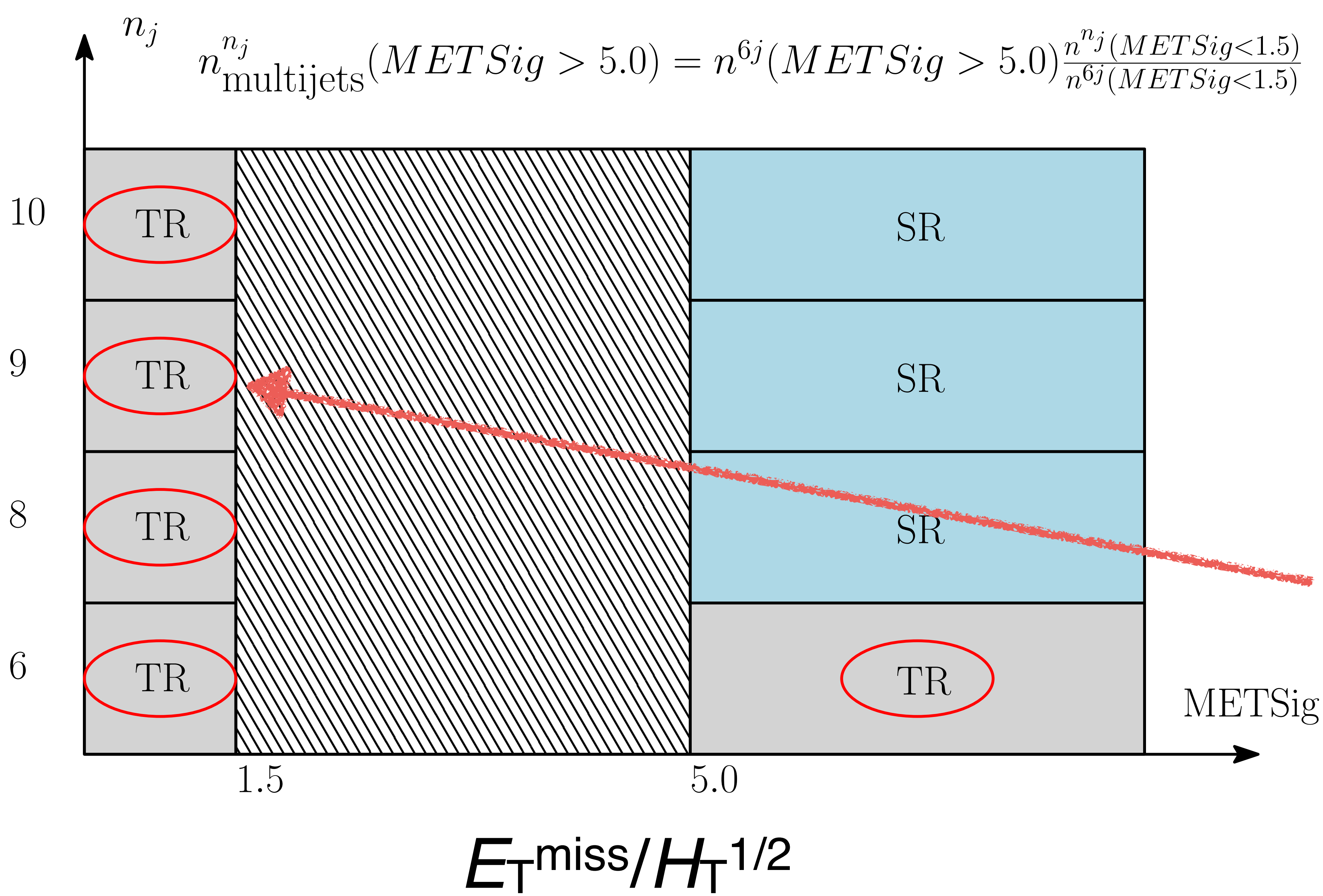

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High Jet Multiplicity Signal Regions

Criterion	Heavy-flavour channel		Jet mass channel
Jet $\lvert\eta\rvert$	< 2.0		
Jet p_{T} N_{jet}	>50 GeV $\geq 8, 9, 10, 11$	>80 GeV $\geq 7, 8, 9$	>50 GeV $\geq 8, 9, 10$
Lepton veto	No preselected e or μ after overlap removal		
b-jet selection Large-R-jet selection	$p_{\mathrm{T}} >50$ GeV and $\lvert\eta\rvert < 2.0$ $p_{\mathrm{T}} >100$ GeV and $\lvert\eta\rvert < 1.5$		
$N_{b\text{-tag}}$ M_{J}^{Σ}	$\geq 0, 1, 2$ ≥ 0		≥ 0 $\geq 340, 500$ GeV
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$	$> 5\,\mathrm{GeV}^{1/2}$		

Signal regions (SRs) are constructed from 7, 8, 9, 10, and 11 inclusive jets (leptons vetoed). Two channels:

•"**Heavy-flavour channel**": 0, 1, and 2 inclusive *b*-jets are required.

High Jet Multiplicity Signal Regions

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Jet $\|\eta\|$	< 2.0		
Jet p_{T} N_{jet}	$>$50 GeV $\geq 8, 9, 10, 11$	$>$80 GeV $\geq 7, 8, 9$	$>$50 GeV $\geq 8, 9, 10$
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$N_{b\text{-tag}}$ M_{J}^{Σ}	$\geq 0, 1, 2$ ≥ 0		≥ 0 $\geq 340, 500\,\mathrm{GeV}$
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$	$> 5\,\mathrm{GeV}^{1/2}$		

Signal regions (SRs) are constructed from 7, 8, 9, 10, and 11 inclusive jets (leptons vetoed). Two channels:

- "**Jet mass channel**": Jets are **reclustered** into larger fat-jets, uses the total fat-jet mass per event (M_{J}^{Σ}).

Results with 36.1 fb^{-1} (2015 + 2016)

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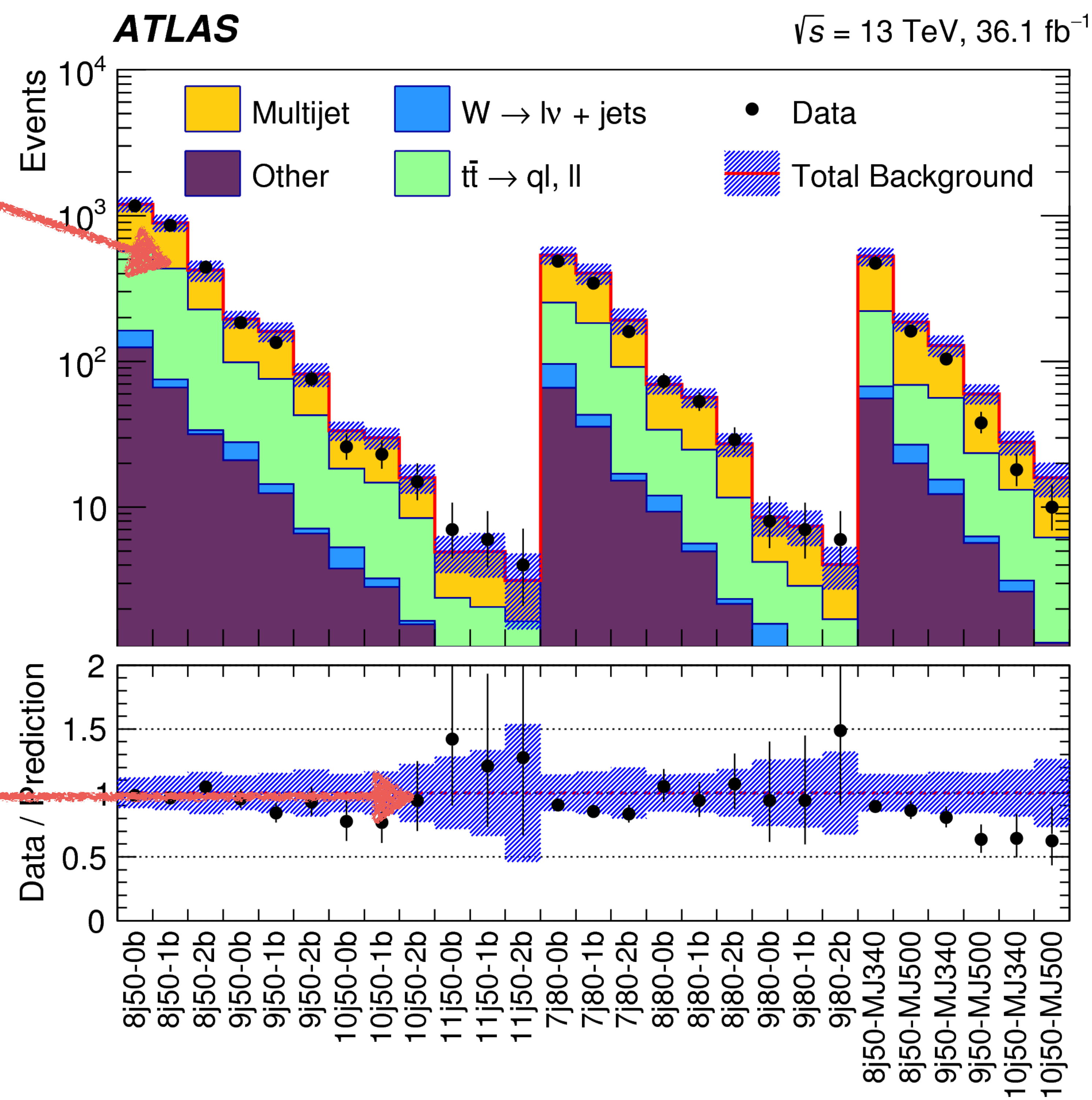
Yields in each of the 27 signal regions — excellent data/(MC + template) prediction.

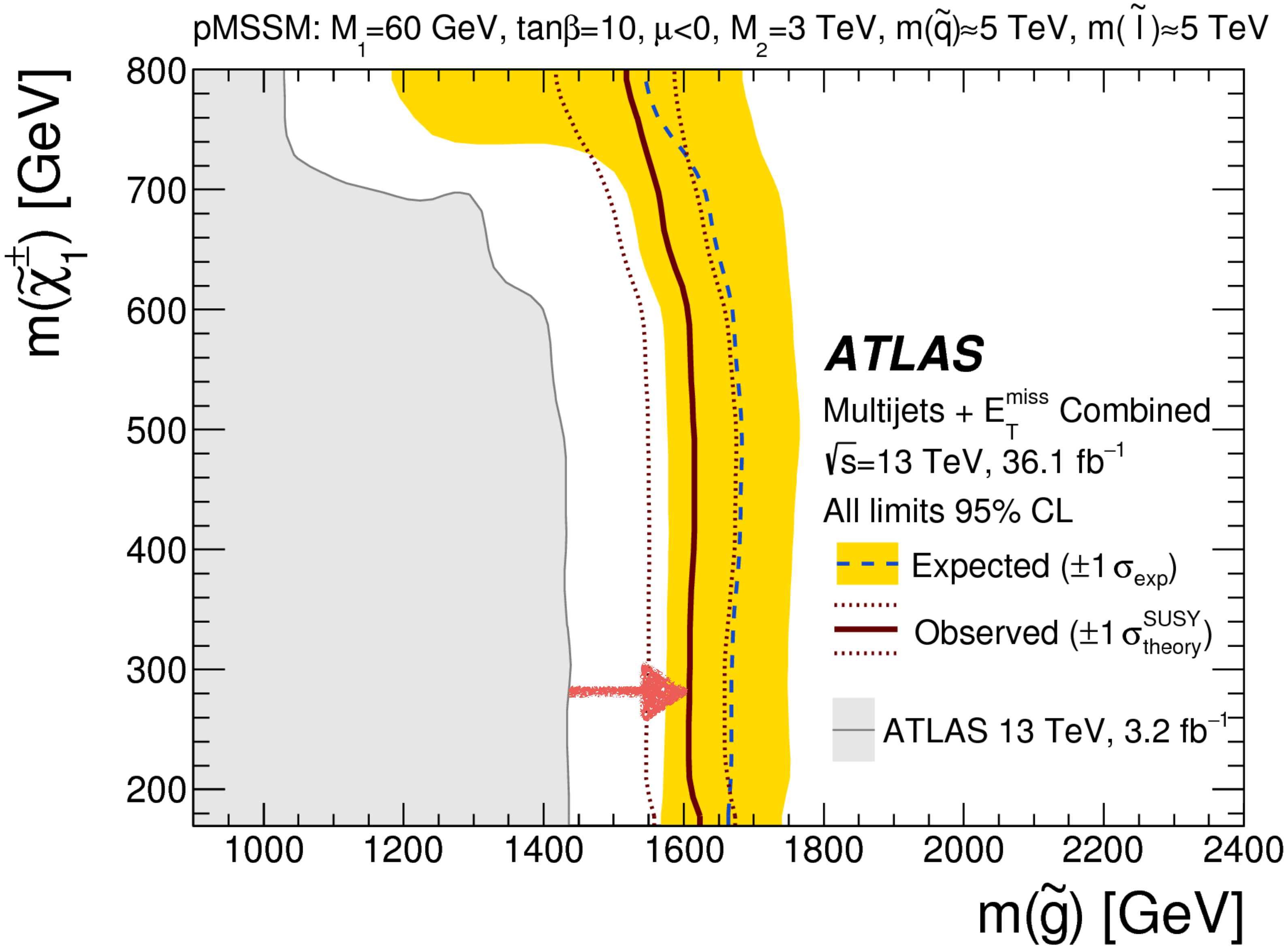
The signal yields in each SR using **2015 + 2016 LHC data**.

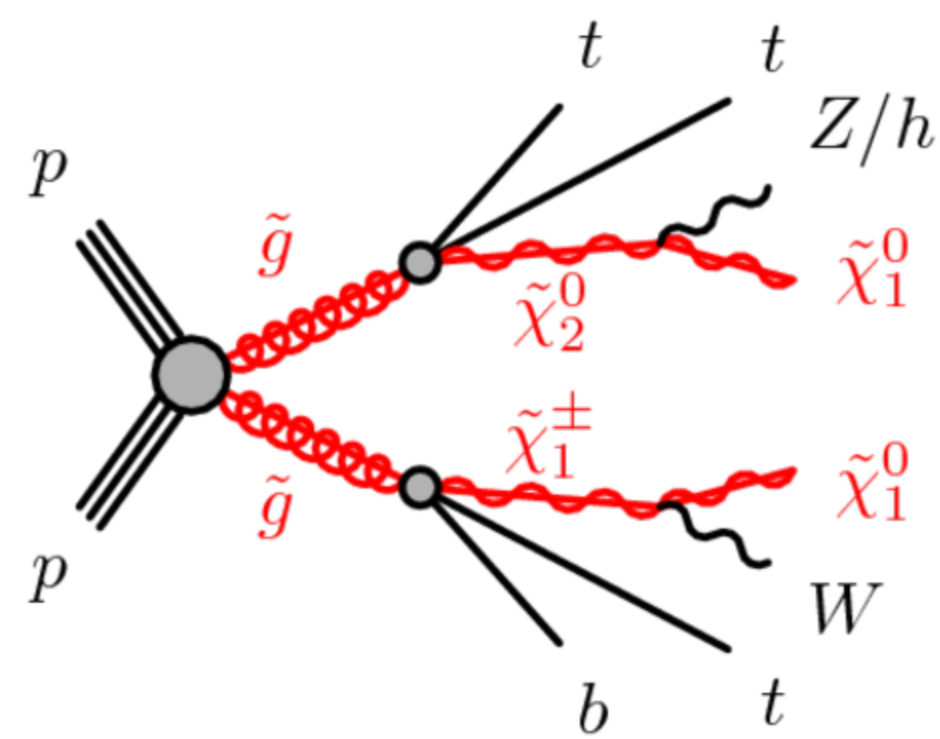
Smoking gun for this new physics search: large SR excesses at moderate E_T^{miss} significance coming from SUSY particle production.

No statistically significant excesses are observed — use this to understand sensitivity to existing SUSY models.



Sensitivity to RPC SUSY

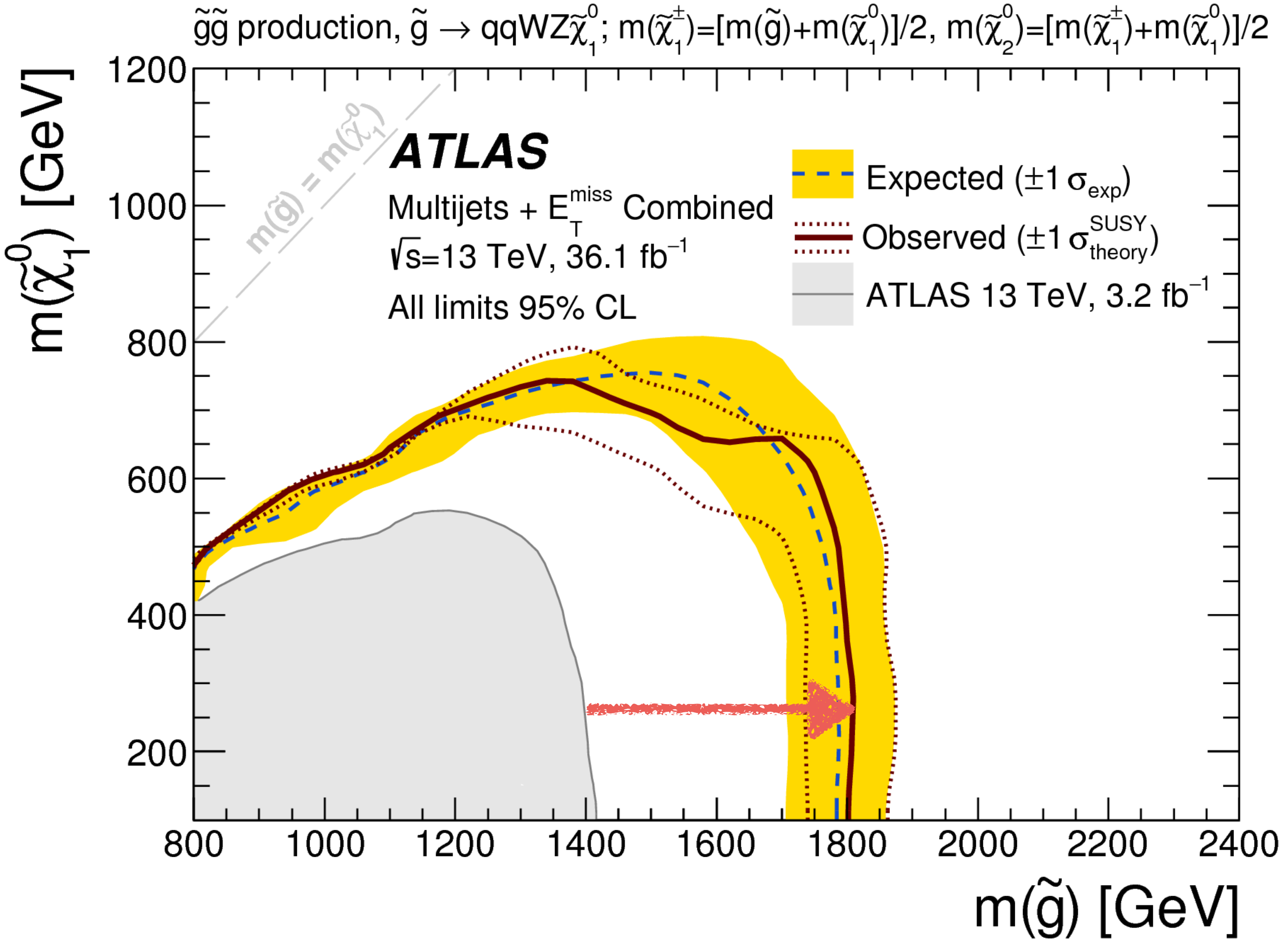


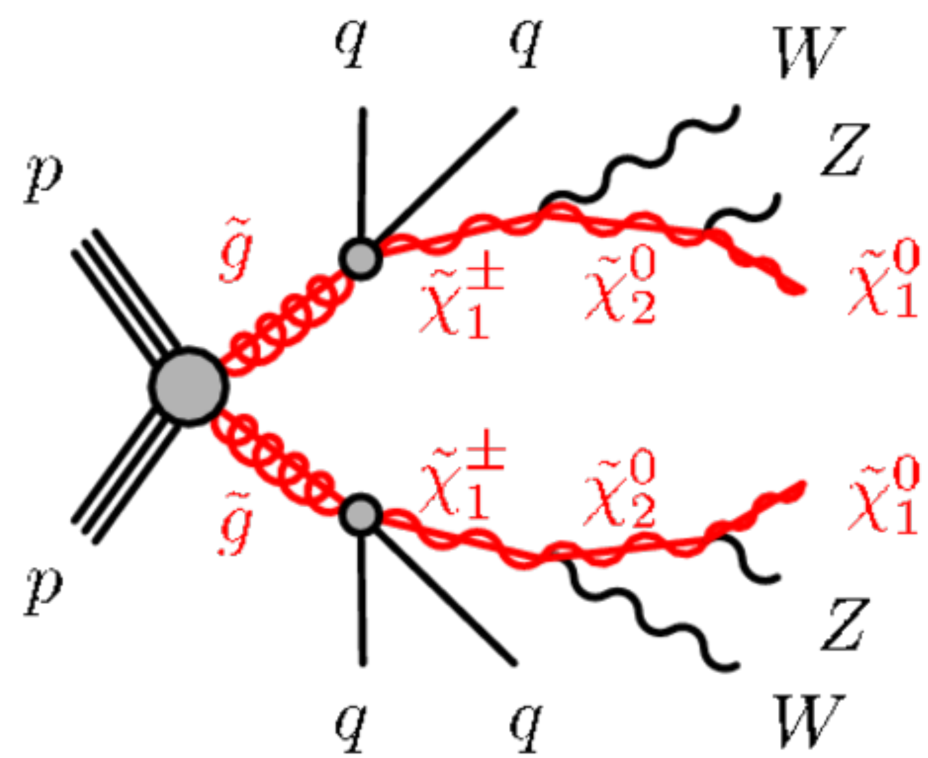


95 % confidence level (CL) exclusion limits are set on different strongly-produced SUSY models: three *R*-parity conserving (pMSSM above), and a fourth model which is *R*-parity violating (RPV) .

Sensitivity to gluino masses extended up to ~ 1.7 TeV.

Sensitivity to RPC SUSY





95 % confidence level (CL) exclusion limits are set on different strongly-produced SUSY models: three *R*-parity conserving (2-step above), and a fourth model which is *R*-parity violating (RPV) .

Sensitivity to gluino masses extended up to 1.8 TeV.

Concept of *R*-Parity

- In the minimal supersymmetric standard model (MSSM), baryon and lepton number are **no longer conserved** by all couplings in the theory.

- We can "force" such *B* and *L*-violating couplings to be forbidden by imposing the **conservation of the *R*-parity** quantum number, defined:

$$P_{\mathrm{R}} = (-1)^{3(B - L) + 2s}$$

Spin number

Baryon number

Lepton number

- SUSY particles: $P_{\mathrm{R}} = -1$

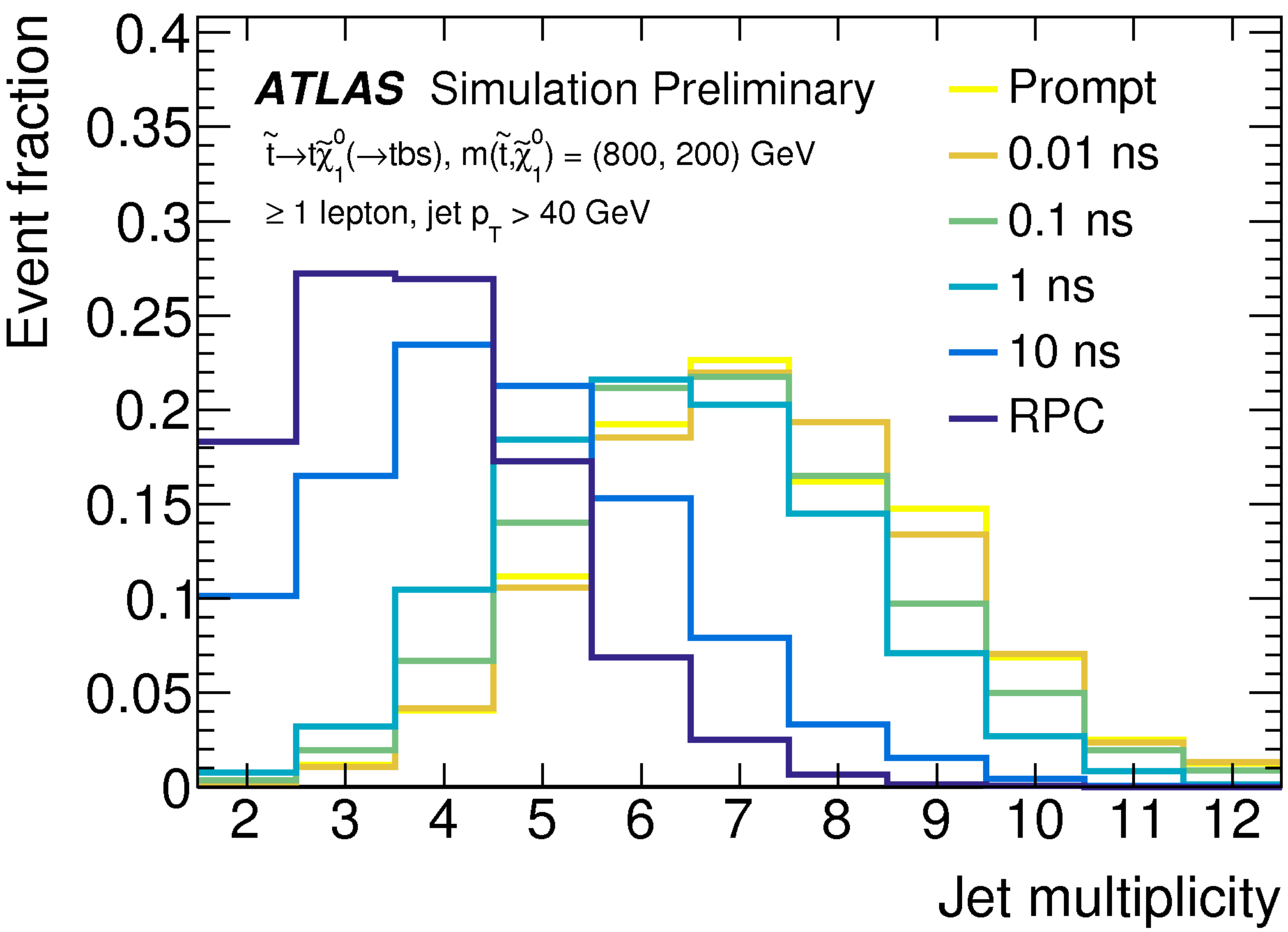
- SM particles: $P_{\mathrm{R}} = +1$

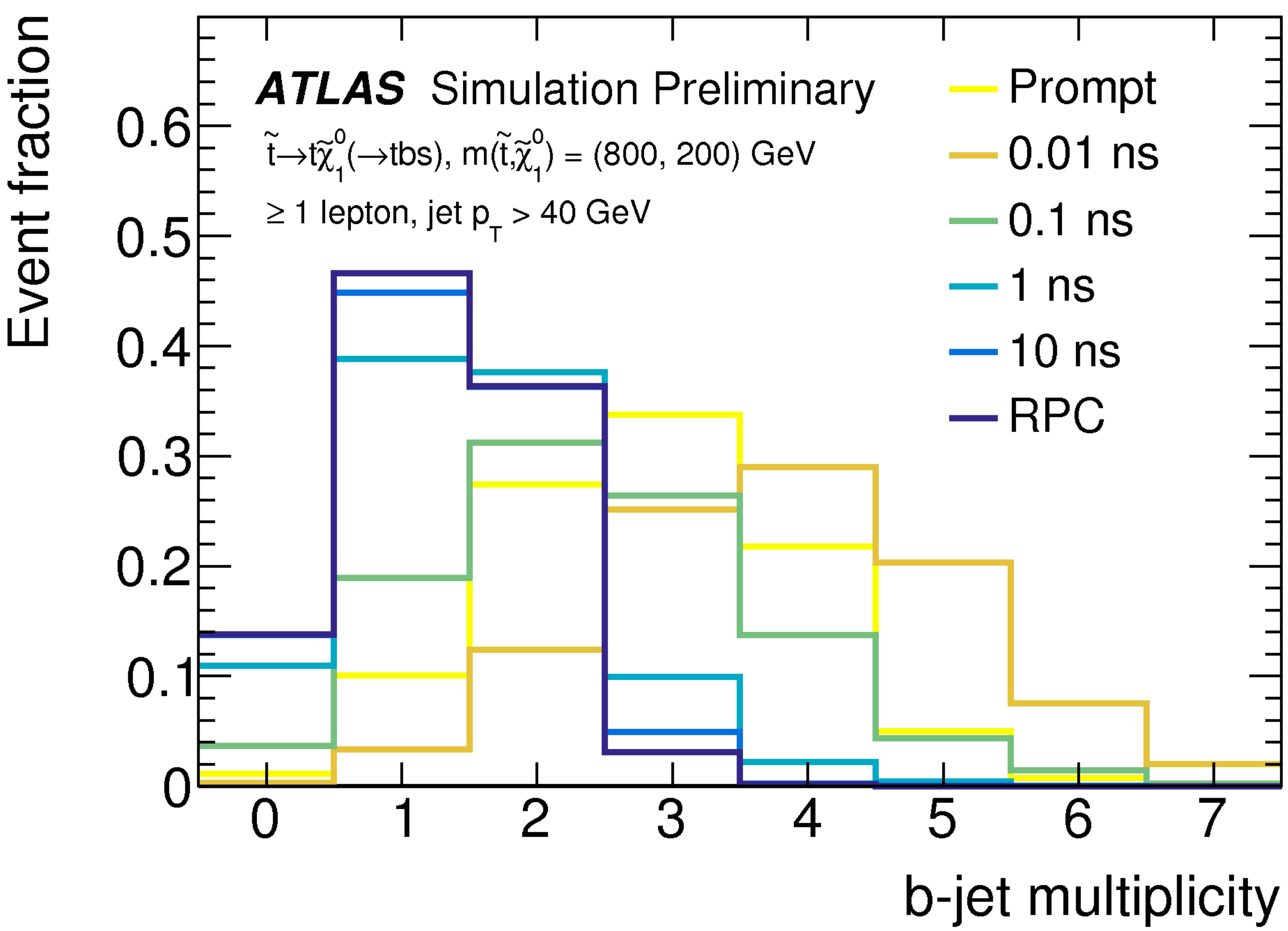
- Our "conventional" SUSY is *R*-parity conserving (RPC) => LSP is stable.

- Interpretation of stable LSP: **dark matter**.

RPC-meets-RPV Kinematics

- Let's understand the kinematics of the various RPC-RPV signals, to see if existing squark/gluino searches could be sensitive …





Turn on RPV coupling =>
jet multiplicity increases

***b*-tagging multiplicity "increases".**
Optimal "*b*-tagging" sweet spot at 0.01 ns.

Summary of Signal Models

Model name	Gqq	Gtt	Stop	R-hadron
Coupling	λ''_{112}	λ''_{323}	λ''_{323}	–
Decay	$\tilde{g} \to qq\tilde{\chi}_1^0$ $\tilde{g} \to qq\tilde{\chi}_1^0(\to qqq)$ $\tilde{g} \to qqq$	$\tilde{g} \to tt\tilde{\chi}_1^0$ $\tilde{g} \to tt\tilde{\chi}_1^0(\to tbs)$ $\tilde{g} \to tbs$	$\tilde{t}_1 \to t\tilde{\chi}_1^0$ $\tilde{t}_1 \to t\tilde{\chi}_1^0(\to tbs)$ $\tilde{t}_1 \to bs$	$\tilde{g} \to qq\tilde{\chi}_1^0$
Other colored sparticle masses	$m(\tilde{q}) = 3$ TeV $m(\tilde{t}, \tilde{b}) = 5$ TeV	$m(\tilde{q}) = 5$ TeV $m(\tilde{t}, \tilde{b}) = 2.4$ TeV	$m(\tilde{q}, \tilde{g}) = 3$ TeV $m(\tilde{t}_2, \tilde{b}) = 3$ TeV	$m(\tilde{q}, \tilde{t}, \tilde{b}) \approx$ PeV
LSP	The LSP is bino-like, $m(\tilde{\chi}_1^0) = 200$ GeV			$m(\tilde{\chi}_1^0) = 100$ GeV

Main Analysis Characteristics

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Analysis name	Leptons	Jets / b-tags	$E_{\mathrm{T}}^{\mathrm{miss}}$ requirement	Representative cuts	Model targeted
RPC 0-lepton, 2-6 jets [53]	0	≥ 4 / –	$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}} > 0.2$	$m_{\mathrm{eff}} > 3000$ GeV	Gqq, R-hadron
RPC 0-lepton, 7-11 jets [55]	0	≥ 7 / – ≥ 11 / ≥ 2	$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}} > 5\ \mathrm{GeV}^{1/2}$	–	Gqq Gtt
RPC multi-b [56]	0 1	≥ 7 / ≥ 3 ≥ 5 / ≥ 3	$E_{\mathrm{T}}^{\mathrm{miss}} > 350$ GeV $E_{\mathrm{T}}^{\mathrm{miss}} > 500$ GeV	$m_{\mathrm{eff}} > 2600$ GeV $m_{\mathrm{eff}} > 2200$ GeV	Gtt
RPV 1-lepton [57]	1	≥ 10 / ≥ 4	–	–	Gtt, stop
RPC Stop 0-lepton [58]	0	≥ 4 / ≥ 2	$E_{\mathrm{T}}^{\mathrm{miss}} > 400$ GeV	$m_{\mathrm{jet,R=1.2}} > 120$ GeV	stop
RPC Stop 1-lepton [59]	1	≥ 4 / ≥ 1	$E_{\mathrm{T}}^{\mathrm{miss}} > 250$ GeV	$m_T > 160$ GeV	stop
RPC and RPV same-sign and three leptons [60]	2 SS or 3	≥ 6 / ≥ 2 ≥ 6 / ≥ 2	$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$¿0.15 –	$m_{\mathrm{eff}} > 1800$ GeV $m_{\mathrm{eff}} > 2000$ GeV	Gtt, stop
RPV stop dijet pairs [61]	–	≥ 4 / ≥ 2	–	$\mathcal{A} < 0.05$	stop
Dijet and TLA [62,63]	–	≥ 2 / –	–	$\lvert y^{*} \rvert < 0.6$	stop